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Aeronautical Engineering REVIEW

April, 1956

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Aeronautical Engineering Review

Vol. 15—No. 4 April, 1956

CONTENTS

24th Annual Meeting—Summary of Technical Sessions 42

The Economics of Large Aircraft ..... *Grover Loening* 48

Silencing the Jet Aircraft ..... *Holden W. Withington* 56

Rocket and Satellite Studies During the IGY ..... *Joseph Kaplan* 64

Problems in the Design of Propeller-Driven Vertical Take-Off Transport Airplanes ..... *M. O. McKinney, R. E. Kuhn, and J. B. Hammack* 68

The Application of Nondestructive Testing by a Manufacturer of Military Aircraft ..... *W. J. Maloney, Jr.* 76

IAS News Notes 33

IAS News 35

Guest Editorial by Dr. James R. Killian, Jr. 38

IAS Preprints 97

Aeronautical Reviews 155

International Aeronautical Abstracts 169

Books 189

Personnel Opportunities 195

Sherman M. Fairchild Publication Fund Papers 197

Index to Advertisers 198

New Products and Product Literature 201

Cover—Goodyear Aircraft Corporation's inflatable airplane takes off on a demonstration flight. Made rigid by low air pressure, the fabric wings and fuselage support a 40-hp. engine and the pilot. Deflated, the plane fits into the rear of a station wagon. Goodyear designed and built the experimental plane to test the possibility of using its Airmat fabric—a rubber-coated, reinforced nylon—as structural material for aircraft. The metal supports and struts are attached with high-strength, fan-shaped patches of rubberized material.

Published Monthly by the

Institute of the Aeronautical Sciences, Inc.

2 East 64th Street, New York 21, N.Y.

***Western Office:* 7660 Beverly Blvd., Los Angeles 36, Calif.**

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□●● Pilot manufacturing, product development and research

XIII
XIV
Cleveland
Chicago

I.A.S. News Notes

April 1956

THE INSTITUTE'S National Summer Meeting in Los Angeles, June 18-21, will consist of 3 days of technical sessions at the IAS Building, a dinner in the Biltmore Hotel, and a field trip to March Air Force Base. Tentative plans call for sessions on Aerodynamic Heating, Operation of Large Turbine-Powered Aircraft, Low-Speed Flight, Economics, Sociological Influences, Nuclear Engineering, Supersonic Propulsion, and Development of the B-52. The Annual Banquet on Wednesday evening, June 20, will be in the nature of a tribute to Theodore von Karman marking his 75th birthday. Hugh L. Dryden, Director of the NACA, will deliver the principal address. Further details will appear in next month's Review.

THE AMERICAN HELICOPTER SOCIETY has scheduled its Twelfth Annual National Forum for May 2-5 at the Sheraton Park Hotel, Washington, D.C. The speaker at the Honors Night Dinner May 3 will be L. B. Richardson, FIAS. Lt. Gen. James M. Gavin, USA, will address a luncheon the following day. IAS members are invited to attend the AHS Forum without paying a registration fee.

A RECENT COUNT shows the Institute now has more than 11,000 graded members and 3,000 student members.

NATIONAL MEETINGS CALENDAR

June 18-21	Summer Meeting, IAS Building, Los Angeles, California.
Aug. 15-17	Turbine-Powered Air Transportation Meeting, Grant Hotel, San Diego, California.

JOINT MEETINGS CALENDAR

May 14-16	IRE National Conference on Aeronautical Electronics, Biltmore Hotel, Dayton. IAS Session on Human Engineering.
Aug. 20-21	National Telemetering Conference, Biltmore Hotel, Los Angeles. Co-sponsored with AIEE, IRE, and ISA.

REGIONAL STUDENT CONFERENCES

Apr. 10	Detroit Section Conference, University of Detroit.
Apr. 13-14	Middle Atlantic Conf., University of Maryland, College Park, Md.
Apr. 19-21	Southwestern Conference, Hotel Adolphus, Dallas, Texas. Sponsored by the Texas Section.
Apr. 20-21	Northeastern Conference, Brown University, Providence, R I.
Apr. 25	St. Louis Section Conference, Congress Hotel, St. Louis, Mo.
Apr. 26-27	Southeastern Conference, Georgia Institute of Technology, Atlanta. Sponsored by the Atlanta Section.
May 3-5	West Coast Conference, IAS Building, Los Angeles. Sponsored by the Los Angeles Section.

I.A.S. News Notes (con't.)

SECTION MEETINGS CALENDAR

Apr. 5 Atlanta Section: Officers Club, Naval Air Station, Chamblee, Ga. Reception 6:30 p.m., Dinner 7 p.m. "Some Experiences with Atomic Weapons" by Alan Y. Pope of Sandia Corporation.

Apr. 5 Philadelphia Section: Joint Meeting with Aero Medical Association and Franklin Institute Labs., at Franklin Institute. Reception 6:30 p.m., Dinner 7 p.m., Meeting 8 p.m. "Supersonic Speeds and Human Tolerance" by Lt. Col. John P. Stapp, Aero Medical Field Lab., USAF.

Apr. 7 Los Angeles Section: Family Night, IAS Building, 6 p.m. Buffet Dinner and Movies. Bring wives and teenagers.

Apr. 10 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "The Free, Shock-Separated, Turbulent Boundary Layer" by Artur Mager of Marquardt Aircraft Company.

Apr. 11 Cleveland-Akron Section: Case Institute of Technology. Dinner 6:30 p.m., Meeting 7:30 p.m. Minta Martin Lecture, "The Aerodynamics of Aircraft Engines," by William R. Hawthorne, of M.I.T.

Apr. 11 Niagara Frontier Section: Cornell Aeronautical Laboratory, 8 p.m. "Problems of Aerodynamic Testing at Hypersonic Velocities" by A. Hertzberg of Cornell Aeronautical Laboratory.

Apr. 12 San Diego Section: IAS Building, 8 p.m. "Reverse Thrust" by Paul P. Datner, Aerojet-General Corporation.

Apr. 13 Indianapolis Section: Marott Hotel. Reception 6:30 p.m., Dinner 7 p.m., Meeting 7:45 p.m. "Air Force Aims in Aeronautical Development" by Brig. Gen. Marvin C. Demler, USAF, of ARDC.

Apr. 17 Columbus Section: Officers Club, Naval Air Station, 8:30 p.m. "Aeroelasticity at High Temperatures" by Robert Laidlaw of North American Aviation, Inc.

Apr. 19 Baltimore Section: Joint Meeting with Washington and Hagerstown Sections at Johns Hopkins Applied Physics Labs., Silver Spring, 6 p.m. Panel Discussion on Survival.

Apr. 19 Dayton Section: Cordell's Supper Club, Fairborn, 6:30 p.m. "Some Trends in Aircraft Accessories" by J. Edward Taylor of Thompson Products, Inc.

Apr. 19 Los Angeles Section: IAS Building. Reception 6 p.m., Dinner 7 p.m., Meeting 8 p.m. "The Development of Rolls-Royce Propeller-Turbine Engines" by D. P. Huddie.

Apr. 19 San Francisco Section: Ramor Oaks Restaurant, Atherton, 8 p.m. "VTOL Aircraft" by Robert J. Woods of Bell Aircraft Corporation.

Apr. 21 Los Angeles Section: Field Trip to Nike Site, 10 a.m.

Apr. 24 Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Asymmetric Disturbances and Stalling in Axial Compressors" by W. Duncan Rannie of California Institute of Technology.

Apr. 24 San Diego Section: IAS Building, 8 p.m. "Supersonic Design Considerations" by Robert J. Woods of Bell Aircraft Corporation.

Apr. 25 St. Louis Section: Congress Hotel, 6:45 p.m. Dinner Meeting for Presentation of Awards in Student Paper Competition.

Apr. 26 New York Section: Suburban Restaurant, Paramus, N. J. Dinner 7 p.m., Meeting 8 p.m. "Training for Flight Beyond the Earth" by J. Gordon Vaeth, Special Devices Center, Office of Naval Research.

IAS News

A Record of People and Events of Interest to Institute Members

Conference on Aeronautical Electronics

IAS Will Participate in IRE's Dayton Meeting with Session on Human Engineering

AGAIN THIS YEAR, the Institute of the Aeronautical Sciences is participating in the Institute of Radio Engineers' National Conference on Aeronautical Electronics, to be held in Dayton, Ohio, May 14–16. Headquarters for the 3-day conference will be the Dayton Biltmore Hotel, and the 22 sessions will be divided between the hotel and the Engineers Club.

The IAS will sponsor the session on Human Engineering, Tuesday afternoon, May 15, at the Engineers Club. The moderator of this session will be J. M. Christensen, Assistant Chief of the Psychology Branch, Aero Medical Laboratory, Wright Air Development Center.

The Dayton Section of the IAS, headed by Chairman W. Donald Dodd, Jr., is handling arrangements for IAS participation in the Conference. There will be a reduced registration fee for IAS members.

▶ Seven papers are scheduled for presentation at the Human Engineering Session. They are:

"Human Engineering Contributions to System Design" by Ralph Queal, Wright Air Development Center, ARDC.

"The Use of Mock-Ups in Air-Borne Equipment Designing" by George W. Michalec, General Precision Laboratory.

"Integrated Cockpit Presentation" by T. J. Thomas, Kearfott Company, Inc.

"New Engineering Techniques in Flight Display Evaluation" by Frank Klimowski, Jr., Stavid Engineering, Inc.

"Collapsing Loss in Air-Borne Radar Displays" by L. E. Mertens, P. N. Nesbeda, and J. P. Mayberry, Radio Corporation of America.

"The PPI Display as a Linear Filter" by Daniel Levine, Goodyear Aircraft Corporation.

"On Flight Instrument Quantization" by L. J. Fogel and D. Jagerman, Stavid Engineering, Inc.

▶ The following subjects will be covered—each by several papers—during the 3-day meeting:

Monday, May 14—*Morning sessions:* Magnetics I, Components I, Semiconductors, Circuits. *Afternoon sessions:* Management, Environment, Electron Tubes I, Testing and Test Equipment.

Tuesday, May 15—*Morning sessions:* Computers I, Components II, Semiconductor Circuits I, Antennas I. *Afternoon sessions:* Human Engineering, Forum on "How to Accelerate Research and Development of Aeronautical Electronics."

Wednesday, May 16—*Morning sessions:* Magnetics II, Radio Interference and Radio-Frequency Cables, Semiconductor Circuits II, Antennas II. *Afternoon sessions:* Computers II, Analysis Techniques, Electron Tubes II, Equipment.

Richard J. Framme, President of the IRE's eighth annual Conference on Aeronautical Electronics, will deliver the welcoming address. He is Chief of the Product Control Office, Directorate of Laboratories, Wright Air Development Center.

The program, according to Mr. Framme, has been planned to meet two objectives: First, to increase the scientific knowledge of the individual and, second, to enhance the professional and social dignity of the individual. The technical papers will cover many phases of the broad subject of aeronautical electronics and will stress the theme "How to do it."

W. Donald Dodd, Jr.

The *Proceedings* distributed at registration will supply a printed record of all technical papers, differing from the previous year's *Digest* in that the complete paper is provided for future reference.

Luncheons are scheduled for Monday and Wednesday. The banquet and dance will be Tuesday evening.

More than 75 industrial exhibits will be on display at the hotel.

▶ The Institute's increasing interest in electronics is shown not only by participation in this IRE meeting in Dayton but by the large number of papers on electronics and related subjects presented at the IAS Annual Meeting in New York. Twelve of these papers will be published in full in the May issue of the REVIEW, which will be the annual special issue on Electronics in Aviation.

Later this year, the Institute will join the IRE, American Institute of Electrical Engineers, and Instrument Society of America in sponsoring the 1956 National Telemetering Conference. This will be held August 20, 21 in Los Angeles.

Nicholas J. Hoff

Hoff Lectures in Europe Under AGARD Auspices

Nicholas J. Hoff, FIAS, Head of the Department of Aeronautical Engineering and Applied Mechanics at the Polytechnic Institute of Brooklyn, made a European lecture tour in January under auspices of the Advisory Group for Aeronautical Research and Development of the North Atlantic Treaty Organization. He is a member of AGARD and until recently was on the USAF Scientific Advisory Board.

The invitation lectures discussed the effects of high temperatures on the structural behavior of supersonic airplanes and missiles, with particular reference to aerodynamic heating, heat transfer in the structure, thermal stresses, thermal buckling, creep, stress distribution in the presence of creep, and creep buckling.

Speaking in French, Dr. Hoff delivered four lectures at the Scuola d'Ingegneria Aeronautica of the University of Rome, two at the Institut Henri Poincaré of the University of Paris, two at the Office National d'Études et de Recherches Aéronautiques (ONERA, the French equivalent of NACA), and one at the University of Liège, Belgium.

After the final lecture, the Medal of the University of Liège was bestowed upon Dr. Hoff in recognition of "the services he has rendered to the aeronautical sciences, to applied mechanics, and to international cooperation in aeronautics among the NATO nations."

Students Present Papers in Eight Competitions

Student members of the Institute are participating this spring in eight Regional Student Conferences, conveniently spotted geographically to attract entries from scores of engineering schools in all parts of the United States.

Conducted by the IAS under auspices of the Minta Martin Aeronautical Student Fund, these meetings provide an incentive for students to write technical papers and enter them in competition. This year's series of eight regional competitions is the largest since the annual conferences were inaugurated in Detroit in 1948. Last year there were six.

At each regional conference, a dozen or more schools are represented by local winners in separate undergraduate and graduate classifications. The youthful authors have the experience of reading their papers personally before an appreciative professional audience. They compete for cash prizes and other honors. Traveling expenses are paid by the Fund.

The winning papers at each regional conference will be published by the Institute in a booklet entitled *1956 First Award Papers*. Plaques will be presented to the two national winners, an undergraduate and a graduate student.

The first regional conference this year took place March 12 at Purdue University. Others are scheduled for this month at the University of Maryland, Brown University, Georgia Institute of Technology, and in Dallas and St. Louis. Two conferences will be held in May in Los Angeles and Detroit. All but two of the conferences are sponsored by IAS Sections in the various areas.

W. A. M. Burden Named Trustee of Columbia

William A. M. Burden, a Past President and Benefactor of the Institute, has been elected a life member of the Board of Trustees of Columbia University.

The former Assistant Secretary of Commerce for Air, who was graduated from Harvard in 1927, is Chairman of the Aviation Advisory Committee of the Harvard School of Business Administration. He is President of the Museum of Modern Art, New York, and active in several charitable and educational organizations. From 1950 to 1952 he served as Assistant for Research and Development to the Secretary of the Air Force.

A number of years ago, Mr. Burden presented a large collection of aviation books, periodicals, and Government reports to the IAS Library.

Uniterm Index Issued by Pacific Aeronautical Library

The Pacific Aeronautical Library of the IAS has adopted the Uniterm system of coordinate indexing for its periodical index, beginning with the 1955 volume. Prior to last year, the material was compiled under subject headings, on cards.

William A. M. Burden

Under the new system, information contained in a collection of documents is analyzed into the simplest practical word units of information, thus giving rise to the name "Uniterm." Each of these basic words is assigned a separate catalog card, and each document to be catalogued is given a serial number. These serial numbers are posted on all cards headed by the Uniterms by which the documents have been analyzed.

For example, suppose a searcher is looking for information on "air-cooled aircraft guns." There is no need for him to search the indexing system for the six possible ways by which this information could be filed. Instead, he has only to select three Uniterm cards, each bearing one of the three subject words, and compare the cards for any and all serial numbers they might have in common. Once the searcher has noted these serial numbers, he knows precisely where all available information on "air-cooled aircraft guns" may be obtained.

About 180 technical periodicals and reports are represented in the 1955 *Pacific Aeronautical Library Index*, which sells for $25. For the first time, it has been published in desk catalog form, with an index of authors. Previously, the index had been distributed to subscribers on cards and sheets. In listing articles, an effort is made not to duplicate work done by the *Industrial Arts Index*, and particular attention is given to British periodicals not covered by *Industrial Arts*.

During 1956, the index is being cumulated quarterly. Accession lists of articles indexed, with Uniterms used, will be issued once a week, and the desk catalog will allow space for articles to be

posted, so that subscribers may keep the index on a current basis if they wish.

For further information on the 1956 index, including price, write the Pacific Aeronautical Library, IAS Western Headquarters, 7660 Beverly Blvd., Los Angeles 36.

MAA Continues Officers

Several IAS members have been re-elected as leaders of the Manufacturers Aircraft Association, Inc., for 1956. The Association administers the patent cross-licensing agreement for the airplane industry in the United States.

Among six Vice-Presidents re-elected at the annual meeting on January 31 were Robert E. Gross, AMIAS; J. H. Kindelberger, Honorary Fellow; Charles H. Chatfield, FIAS; and John A. Sanborn, AFIAS, who is General Manager of the Association. James M. Clark, MIAS, was re-elected Assistant Treasurer and Assistant Secretary.

Among the Directors re-elected were Mr. Chatfield, Robert R. Osborn, FIAS; L. B. Richardson, FIAS, and George C. Sullivan, MIAS.

Sigma Gamma Tau

Four members of the Institute are guiding Sigma Gamma Tau, the national honorary aeronautical engineering society, which now has 15 chapters.

Henry S. Stillwell, MIAS, Head of the Aeronautical Engineering Department of the University of Illinois, is President. Henry Burlage, Jr., MIAS, Assistant Professor of Aeronautical Engineering at Case Institute of Technology, is First Vice-President. John J. Harper, MIAS, Associate Professor in the Daniel Guggenheim School of Aeronautics, Georgia Institute of Technology, is Second Vice-President. Harry H. Hilton, AFIAS, Assistant Professor of Aeronautical Engineering at the University of Illinois, is Secretary-Treasurer. These four men also comprise the National Executive Council.

Membership in the honorary society is open to juniors, seniors, and graduate students studying aeronautical engineering or aero options in ECPD-accredited colleges.

Don R. Berlin, FIAS, President of Vertol Aircraft Corp., has been elected Chairman of the Helicopter Council of the Aircraft Industries Association.

NEWS OF MEMBERS

▸ **William F. Ballhaus** (AF), Chief Engineer of Northrop Aircraft, Inc., has been reappointed to the NACA's Committee on Aircraft Construction.

▸ **E. Arthur Bonney** (M), Head of the Aerodynamics Group of the Applied Physics Laboratory, The Johns Hopkins University, has been given the Engineering Science Award of the Washington Academy of Sciences for "outstanding contributions in the field of supersonic aerodynamics."

▸ **Leslie A. Bryan** (M), Director of the Institute of Aviation at University of Illinois, has been elected a Vice-President of the National Aeronautic Association.

▸ **Gen. Benjamin W. Chidlaw, USAF (Ret.)** (F), Vice-President of Thompson Products, Inc., was General Chairman of the National Model Plane Show held in Cleveland last month.

▸ **Lee L. Douglas** (M), Vice-President—Engineering, Vertol Aircraft Corporation, has been named Chairman of the NACA's Subcommittee on Helicopters. He also is a member of the NACA's Committee on Aerodynamics.

▸ **John A. Drake** (M), Director of Long-Range Plans and Research, Marquardt Aircraft Company, has been reappointed to NACA's Subcommittee on Internal Flow.

▸ **William R. Enyart** (AF), President of Simmonds Aerocessories, Inc., has been appointed to the Executive Committee of the National Aeronautic Association.

▸ **Lt. Col. Leon S. Jablecki, USAF** (M), of Headquarters, Air Research and Development Command, has been appointed to the NACA's Subcommittee on Aircraft Loads.

▸ **Roger W. Kahn** (M), Service Manager and Test Pilot of Grumman Aircraft Engineering Corporation, has been appointed to the Executive Committee of the National Aeronautic Association.

▸ **Frederick B. Lee** (M), former CAA Administrator, has been elected President of the Aero Club of Washington.

▸ **George N. Mangurian** (AF), Chief of Structures, Northrop Aircraft, Inc., has been reappointed to the NACA's Subcommittee on Aircraft Structures.

▸ **Capt. W. T. McGinness, USAF** (TM), of Headquarters, Air Research and Development Command, has been appointed to the NACA's Subcommittee on Aircraft Structures.

▸ **Paul A. Pitt** (M), Chief Engineer of Solar Aircraft Company, has been reappointed to the NACA's Subcommittee on Combustion. He is a specialist in gas-turbine theory and design.

▸ **Robert F. Robinson** (M), Assistant Chief of the Aerodynamics Branch, Air Research and Development Command, USAF, has been appointed to the NACA's Subcommittee on Seaplanes.

▸ **Harry Tobey** (M), Chief of Structures, Vertol Aircraft Corporation, has been appointed to the NACA's Subcommittee on Aircraft Loads.

▸ **Don L. Walter** (AF), Vice-President—Engineering, Marquardt Aircraft Company, has been reappointed to the NACA's Subcommittee on Engine Performance and Operation.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Paul D. Arthur (M) has joined Marquardt Aircraft Company, Van Nuys, Calif., as a Research Scientist. He was formerly with the Guided Missile Research Division of The Ramo-Wooldridge Corporation.

Emmet E. Baker, Jr., (M) has been named Manager of the Electronics Division of Chamberlain Aviation, Inc., Akron, Ohio. He is in charge of systems engineering of radio and radar installations in executive aircraft. He was formerly with Bendix Aviation Corporation, Baltimore.

(*Continued on page 128*)

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Dr. James R. Killian, Jr.
President
Massachusetts Institute of Technology

America's Capacity to Maintain Technological Leadership*

Guest Editorial

* Honors Night Dinner Address, 24th Annual Meeting, IAS, N.Y., Jan. 23–26, 1956.

Today the economic strength of all nations depends increasingly upon that combination of science, engineering, and industry which we call technology. So, too, does the safety of the free world. In a frightening degree, the deterrence of total war and the integrity of the free world depend upon America's capacity to maintain a position of great relative technological strength in both the economic and military measures and in the countermeasures of the cold war.

As we face this challenge to American technology, we watch the Soviets' steady growth in technological strength. The Soviet success in achieving an educational output of scientists and engineers greater than our own has brought an awakened realization of the present responsibilities of our own educational system. At this critical point, we discover that we face an almost irremediable shortage of teachers as our manpower needs reach their peak—and just at the time the

Soviets seemingly have achieved a nearly adequate cadre of teachers.

As we look more closely at published reports of Soviet progress, we see other impressive accomplishments in technology. Russia apparently has a master plan—a grand strategy—expressing long-range state objectives for technological advance. Her educational program, the preferential treatment of scientists, and the liberal funds available for research all indicate a massive mobilization to achieve technological strength.

We observe too that the Russians have an extremely well-articulated, monolithic organization for research and development rapidly responsive to the plans of the state and impressively agile in translating ideas—sometimes our ideas but many good ones of their own—into hardware; this includes nuclear weapons and the capacity to deliver them. Perhaps one of their greatest secret weapons is their swift and consistent follow-through from idea to practice.

We note next that the Soviets have outdone the capitalistic nations in their remarkably uninhibited use of capitalistic incentives to extend and better the quality of their education of scientists and engineers. In the past 50 years, as the recent Ruml study showed, the economic position of our top professors has deteriorated relatively more than that of almost any other group in America. In the past 25 years, in sharp contrast, Soviet professors have moved into the top brackets in salary and status in the U.S.S.R. In Russia, when a young man gets the equivalent of our Ph.D., he may be awarded a lifetime stipend, and as a teacher he may receive an additional stipend for every student he helps through to an advanced degree—a sort of academic piecework arrangement. His scientific papers may be purchased and published by the state, leading inevitably to a multiplication of papers and many of low quality. Altogether, the professional educator in science and engineering stands at the top of the ladder of prestige and reward in the U.S.S.R., and, by American standards, he has the benisons that great wealth bestows in this country.

At the insistence of the Soviet Academy of Sciences, the top scientists and engineers are apparently induced, if not required, to teach or hold administrative posts in the major academies, universities, and institutes of technology. Thus, most of the leading aeronautical engineers in Russia have educational responsibilities. General Tupolev, dean of Soviet bomber designers, is a full professor; Boris Yur'yev, an important figure in applied aerodynamics, is Deputy Minister of Higher Education for Engineering Training. This kind of close coupling between practice and teaching contributes to an effective marriage of theory and practice, but there is evidence, too, that these multiple duties sometimes reduce the quality of teaching.

There also seems to be good evidence that the Soviets have achieved impressive success in reducing the time lag between ideas and hardware. In drawing a comparison with the decision-making structure of the United States with its extensive checks, budgetary reviews, design changes, and Congressional debate, an informed American observer has estimated that 1 to 3 years are eliminated by the Soviets in the speed with which they are able to move from initial design to production on as complex a weapon as, for example, a long-range bomber.

Finally, the Soviets are driving so hard to augment and exploit their basic research that they are willing, in certain fields of critical importance, to let the scientists, rather than the budget officers, determine how much money will be spent and for what purpose. They seem to have now—at least, in a limited number of fields—the kind of crash programs we had in wartime.

What I have said so far should not be interpreted to mean that all is rosy for the professional educator in the Soviet Union. I have emphasized strong points which contribute to Soviet scientific successes in security areas. It should also be remembered that the scientific community in those noncritical areas which are of secondary importance to military security have fared badly at times in terms of the terrible subordination of their intellectual integrity to political dogma.

I have directed your attention to these random samples of how Russia marshals her resources for technological advance, not to claim that the Soviets are superior (which I do not believe) nor to imply that we should copy her methods or that all these are better than ours, but to point up the importance of avoiding complacency with respect to our own methods.

In avoiding complacency, however, let us not be panicked into unwise competition. I hope we do not set as our goal an academic numbers race with the Russians. The Russian educational system serves the state, ours the individual. The Russians are highly specialized in their scientific and engineering education, and we are trending at the undergraduate level toward more fundamental, generalized education. Our objectives and our trends are more likely to serve our nation well and to give us the scientific and technological strength which will be indigenous and, therefore, in accord with our special qualities and ideals.

We should not be isolated and parochial in our science and technology. We need to know what is happening elsewhere and to profit from this knowledge. The Geneva Conference of last August left no doubts of the value of internationally exchanging scientific ideas and information within the limits of prudent security.

No one with any real understanding of our relative technological position as a nation can doubt the evidence that we face stiff competition and that we must marshal and conserve our resources wisely if we are to maintain the technological superiority we now have. Within the context of our American system, we must achieve a grand plan but *by consensus*—not by centralized control—a plan which will give direction and velocity to our technological advance and maximum incentive to private initiative. I venture to suggest . . . a seven-point program for achieving these objectives.

(1) We must seek quality and excellence even at the expense of quantity. Our need is for better science, greater creativity, more advanced engineering, and superior weapons. Above all, our need is for emphasis on superior scientists and engineers. . . .We may have become bemused by numbers and by oversimplified quantitative measures and remedies in evaluating our manpower needs. There can be no reasonable doubt that we have an acute shortage of available, effectively used competence in many fields of technology. Nor can there be any reasonable doubt that this scarcity is a clear and present danger to the nation and to the entire free world. My view does not involve challenging this scarcity or its danger to the nation. It does emphasize that the most acute shortage we now face is that of high intellectual talent adequately educated and in the right place.

One has only to talk with the placement officers of our scientific and technological institutions or with the research directors and chief engineers of industry to get revealing evidence of the special kinds of engineering skills now most urgently needed. These checks indicate a great shortage of young engineers with a mastery of mathematics and of engineering science and thus a competence to handle new, advancing technologies or the ability to enter new fields beyond the grasp of handbook engineers. There is also an acute shortage of project engineers and men with the skills and imagination to direct research and development.

(2) If these views of our manpower needs are correct, they hold important implications for our educational program. They emphasize the need in our secondary schools for greater attention to the superior student. They point up the need to reduce the current loss of exceptional talent shown by the fact that nearly 60 per cent of the top quarter of ability of high school graduates are failing to complete 4 years of college.

The shortage of quality calls for more emphasis in our society on the value of hard intellectual labor. So far, we have managed to get along in the United States by displaying an attitude of condescension toward hard work in our schools. There has been avoidance, if not evasion, of the intellectual tax which must be paid if our intellectual budget is to be balanced. At a time when we are forced to match wits on every front with an alert enemy of growing prowess, America's survival requires that the American people reduce the anti-intellectualism in their schools.

The need for quality calls also for shoring up the sagging emphasis on science in both secondary schools and colleges and for bold efforts to replenish the decimated ranks of science teachers—not with culls from other fields but with teachers possessing a grasp of science and the perception to identify and encourage young people with the bent and capacity for science.

Knowledgeable people in both education and industry are concluding that engineering education is also due for a thorough reassessment. Against the higher compensation and other attractions offered by industry and other noneducational organizations to scientists and engineers, engineering schools are now more vulnerable and more in danger of serious deterioration than other educational institutions. They are more vulnerable, even, than the schools of science. The university and the institute of technology are natural habitats for creative scientists. They are not, generally speaking, quite such natural habitats for engineers whose professional work lies so much in industry and in the field.

The engineering schools are especially vulnerable now because their young and imaginative graduates and teachers—especially those in the advancing, growing fields of technology—are more in demand for noneducational employment than any other group in our educational institutions.

(*Continued on page 85*)

24th Annual Meeting

New York
Jan. 23–26, 1956

Summary of Technical Sessions

The Institute's Twenty-Fourth Annual Meeting in New York attracted a registration of 2,300 members and guests, outdistancing last year's attendance of 1,500, which set a record at the time.

The Grand Ballroom of the Sheraton-Astor Hotel was filled to capacity on the evening of January 23, when almost 1,700 attended the Honors Night Dinner. This event, as usual, was "sold out" several days in advance. The three luncheons together attracted 400 guests.

More papers were presented at this year's Annual Meeting than ever before. There were 77 technical papers and three nontechnical papers, plus a panel discussion. Several new subjects appeared on the program. Throughout the 4-day conference, three sessions were in progress simultaneously except on the last afternoon when there were two.

Besides the 23 technical sessions, the program included an Historical Activities Meeting, the Institute's Annual Business Meeting, luncheon meetings of the IAS Council and of Section Chairmen, several committee meetings, and a reunion for M.I.T. alumni.

Many of the 80 papers presented at the Meeting have been or will be published in full in the REVIEW *or the* JOURNAL. *Available preprints of the papers are listed on page 97.*

We are indebted to the various Session Chairmen for both the excellent manner in which they conducted their sessions and for providing the summaries, which follow in alphabetical order.

Aerodynamics—I

by
Harold T. Luskin

Asst. Chief, Aerodynamics Section
Santa Monica Division
Douglas Aircraft Company, Inc.

The Aerodynamics—I session took place on the morning of Monday, January 23, 1956, in the North Ballroom of the Sheraton-Astor Hotel. The room was well filled with a representative audience from industry, colleges, and Government laboratories. The papers in the session were of unusual interest. The first two described oscillations in supersonic boundary layers and the related transition to turbulent flow. The second two were on the problem of drag at transonic and supersonic speeds.

The first paper was entitled, "Experiments on Laminar Boundary-Layer Oscillations in Supersonic Flow," by John Laufer, Research Specialist, and Thomas Vrebalovich, Research Engineer, California Institute of Technology. It was presented by Dr. Laufer and described hot-wire measurements in laminar boundary layers in the supersonic wind tunnels of the Jet Propulsion Laboratory. The measured energy spectrum of the flow disturbances was shown. Dr. Laufer then showed that the peak energy had a frequency which correlated with the boundary-layer Reynolds Number. He also demonstrated that this frequency was consistent with the results of Lin and Lees in theoretically predicting boundary-layer instability.

The next paper was entitled, "A Study of the Transition to Turbulence of the Laminar Boundary Layer at Supersonic Speeds," by Ronald F. Probstein, Associate Professor of Engineering, Brown University, and Consultant, AVCO Manufacturing Corporation, and by C. C. Lin, Professor of Mathematics, Massachusetts Institute of Technology, and Consultant, AVCO Manufacturing Corporation. The paper was presented by Dr. Probstein, who began with a review of the factors affecting transition at high speeds. These factors included the Mach Number, the body geometry and angle of attack, the temperature of the body surface, the roughness of the surface, the disturbances existing in the stream, suction and injection at the surface, and the physical properties of the gas. He went on to review the data on transition and indicated that most fit into a pattern which could be used to help analyze other cases. Dr. Probstein ended with a suggested program for future study of transition phenomena.

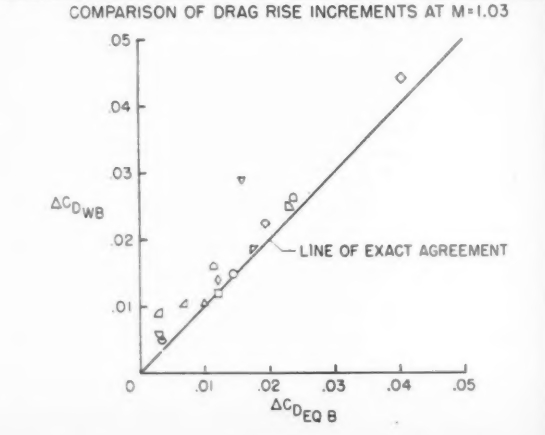

FIG. 1.

Photo courtesy Cornell Aeronautical Laboratory

Just for the record, the photographer snapped this picture of the audience at one of the technical sessions of the Twenty-Fourth Annual Meeting in New York. This session on Helicopter Dynamics, cosponsored by the American Helicopter Society, was held in the North Ballroom of the Sheraton-Astor Hotel.

The third paper of the session was entitled, "Zero-Lift-Drag Characteristics of Wing-Body Combinations at Transonic Speeds," by Richard T. Whitcomb, Aeronautical Research Scientist, Langley Aeronautical Laboratory, NACA. Mr. Whitcomb, winner of the 1955 Collier Trophy for his work in this field, presented physical descriptions of the bases and the applications of the transonic area rule. He pointed out that the area rule states that the sonic pressure drag of a thin, low aspect ratio wing-body combination is like that of the equivalent body, the body of revolution with the same axial distribution of cross-sectional area. The concept was shown to be verified by a comparison of the sonic region drag rise for equivalent bodies and that for actual wing-body combinations as is seen in Fig. 1. The paper went on to consider the beneficial reduction in drag which results from contouring the fuselage to produce a smooth axial area distribution for the wing-body combination. Nacelles were also shown to be subject to study by this rule. All of these concepts were illustrated with experimental data like that in Fig. 2. In this figure is shown the drag rise for wing-body combinations, for the bodies alone, and for the wing-body combinations with the body contoured to make the equivalent body of the combination like the body alone. Favorable transonic drag changes resulted.

The final paper, by Harvard Lomax and Max A. Heaslet, Aeronautical Research Scientists, Ames Aeronautical Laboratory, NACA, was entitled, "Recent Developments in the Theory of Wing-Body Wave Drag." Mr. Lomax, who presented the paper, began with a discussion of the calculation of the wing-body wave drag in terms of the oblique area distribution. He then

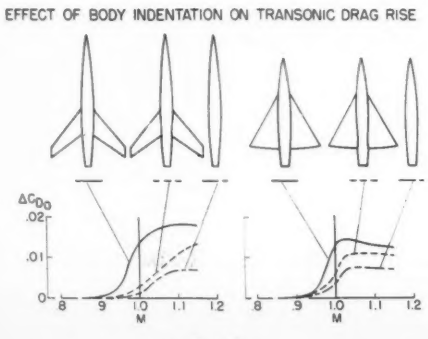

FIG. 2.

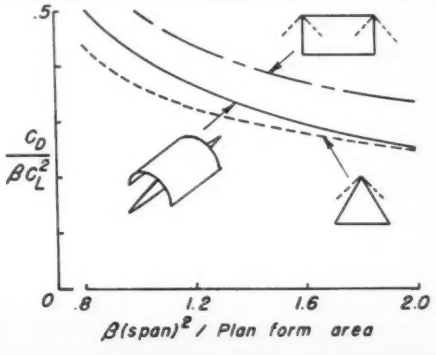

FIG. 3.

Winners of the four IAS awards for 1955 presented at the Honors Night Dinner are shown with 1955 President Robert E. Gross. *From left to right:* Giles J. Strickroth, winner of the Sperry Award; Capt. Wilbur E. Kellum, USN, Jeffries Award; Mr. Gross; Harvey Julian Allen, Reed Award; and Lt. Col. Robert C. Bundgaard, USAF, Losey Award.

described the supersonic area rule and pointed out certain limitations in its use. One of these limitations could be removed by including the force distributions, as well as the oblique area distributions, in the drag formula. The paper went on to take up wing-body combinations with noncircular fuselages. In addition, asymmetric wing locations were studied—as shown, for example, in Fig. 3 where the total drag of a fuselage and a half-ring lifting wing is seen to be of the same order as the drag of lifting wings alone. The paper concluded with a brief discussion of some transonic drag problems.

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Aerodynamics—II

by
Francis H. Clauser
Chairman, Department of Aeronautics
The Johns Hopkins University

The second session on aerodynamics had as its general theme the behavior of nonsteady aerodynamic phenomena. The first paper was by Robert G. Loewy, Chief Dynamics Engineer of the Piasecki Helicopter Corporation, and was entitled "A Two-Dimensional Approximation to the Unsteady Aerodynamics of Rotary Wings." The rotor of a helicopter generates a helically intertwined pattern of trailing vortices whose flow field is not easily calculated. When the helices are nearly flat, the mutual coupling between the vortex field and the rotor blade may induce various kinds of flutter. To investigate such cases, Mr. Loewy viewed the successive vortex layers at a given radius as forming a two-dimensional pattern. He then computed the resulting unsteady lift and moment characteristics. These were then used in a strip theory type of analysis to sum up the effects at various radii in order to give the unsteady behavior of the complete rotor.

The second paper, entitled "Transient Stresses in Airfoils Under Elast Loading," was given by Dr. F. J. Marshall of the University of Chicago who had written the paper in collaboration with Prof. H. F. Ludloff of New York University. When an airplane or a guided missile is struck by the blast wave from an explosion, it is of interest to know the elastic response of the wing or the tail as the wave sweeps across them. The velocity of the blast wave may be faster or slower than the speed of elastic waves in the wing or tail, giving rise to two different types of response. The authors have obtained solutions for both cases. These solutions show in an interesting way how the transient deflections and stresses develop during the passage of the blast wave. This is in contrast to the usual methods of assuming the blast loading is instantaneously or impulsively applied.

The third paper on the "Dynamic Performance of Aircraft" was presented by D. O. Dommasch, President of DODCO, Inc., who is also a professor at Princeton University. Mr. Dommasch defined dynamic performance as the study of airplane motions in the large. As an example he cited the problem of determining the flight program which would give the minimum time to climb from one point to another. The author stated that he has carried out rather extensive machine computations to integrate the nonlinear equation of motion in such a way as to minimize or maximize quantities such as time, distance, or radiation exposure.

The fourth paper was entitled "Probe Measurement of Pressure Distribution on Oscillating Wings in Supersonic Flow." The paper was presented by Dr. E. Mollø-Christensen who had written it in collaboration with R. L. Halfman and S. D. Lewis, all of the Massachusetts Institute of Technology.

In order to measure pressures on a rapidly oscillating

L. B. Richardson *(left)* and Harry F. Guggenheim *(right)* congratulate Theodore von Kármán upon winning the Daniel Guggenheim Medal for 1955. Admiral Richardson was Chairman of the Board of Award.

airfoil and at the same time not subject the pressure element to the oscillating accelerations, the authors have developed a probe which they traverse over the top of the airfoil. The probe itself is a slender, pointed tube, with a static pressure opening on the side communicating to a small barium titanate element.

In order to avoid the drudgery of data reduction, the output of the probe is recorded on a magnetic tape and then fed into an analog computer which analyzes the results and gives a final plot of amplitude and phase angle versus time. The authors have analyzed in some detail the errors which are characteristic of this method of measurement. They have attempted, where possible, to reduce such errors.

Aeroelasticity

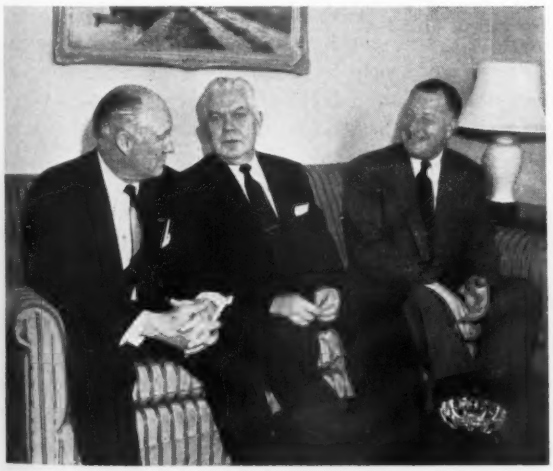
by
Maurice A. Biot

Research Consultant
Cornell Aeronautical Laboratory, Inc.
and Shell Development Company

After a period of about 20 years of development, aeroelasticity as a branch of the aeronautical sciences has finally come into its own. In some areas it has reached the state of classical knowledge, and this year two major textbooks on the subject have been published in this country.

There are still many obscure questions left for elucidation, particularly in the area of nonlinearity. Among the papers presented at this session, two were concerned with nonlinearity. But also among the better known subjects, many points still remain to be covered, such as the influence of sweep on flutter or the effect of certain types of structural change.

One of these structural factors was discussed in a paper, "Effect of Rib Flexibility on the Vibration Modes of a Delta Wing Aircraft," by Wilhelmina D. Kroll.



Charles E. Rosendahl *(left)* and William Littlewood *(right)* talk things over with President Edward R. Sharp between sessions at the Annual Meeting. Admiral Rosendahl made a luncheon speech on aircraft noise, and Mr. Littlewood conducted a session on the same subject.

Theodore von Kármán, Chairman of NATO's Advisory Group for Aeronautical Research and Development, speaks at one of the luncheons held during the Twenty-Fourth Annual Meeting in New York. His subject was "Freedom in Organized Research."

This was a systematic study to determine whether decreasing the number of ribs or making the ribs more flexible would have any appreciable effect on the vibration modes and frequencies of a delta wing aircraft. The modes and frequencies were computed for the basic wing and for the following modifications of the basic wing: (1) one rib outboard of the fuselage removed, (2) two ribs removed, (3) stiffness of ribs outboard of fuselage reduced one-half, and (4) rib stiffness reduced nine-tenths. The results indicated that the frequencies and mode shapes of the modified wings differed little from those of the basic wing and, therefore, that these changes would not appreciably affect the vibration characteristics of the delta wing.

A paper entitled "Pistol Theory—A New Tool for the Aeroelastician" was presented by H. Ashley and G. Zartarian. Representative applications were described which illustrate the extent to which simplifications in the solutions of high-speed, unsteady aeroelastic problems can be achieved through the use of certain aerodynamic techniques known collectively as "piston theory." Based on a physical model originally proposed by Hayes and Lighthill, piston theory for airfoils and finite wings has been systematically developed by Landahl, utilizing expansions in powers of the thickness ratio δ and the inverse of the flight Mach Number M. When contributions of orders δ/M^3 and δ^2/M^2 are negligible, the theory predicts a point-function relationship between the local pressure on the surface of a wing and the normal component of fluid velocity produced by the wing's motion. The computation of generalized forces in aeroelastic equations, such as the flutter determinant, is then always reduced to elementary integrations of the assumed modes of motion. Essentially closed-form solutions were given for the bending-torsion and control-surface flutter properties of typical-section airfoils at high Mach Numbers. Wing-thickness and profile-shape effects were also discussed.

Other applications to unsteady supersonic problems

were reviewed, including gust response and rapid maneuvers of elastic aircraft.

In connection with the applications to panel flutter, attention of the chairman was called to some fundamental work done during the war on V-2 panel flutter. This work is given a short account in the December, 1955, issue of *Zeitschrift fuer Luftwissenschaften*, by P. F. Jordan, and in a Glenn L. Martin report ER 7914.

The effect of nonlinear structural terms on the flutter of a wing and of a system including a control surface was the object of the paper, "On Investigation of Effects of Certain Types of Structural Nonlinearities on Wing Control Surface Flutter," by D. S. Woolston, H. L. Runyan, and R. A. Andrews. Several types of nonlinearity in the stiffness were investigated, including free play, a hysteresis loop, and cubic variations. These were introduced in the torsional degrees of freedom of the wing and in the aileron stiffness in the three degree of freedom system. Calculations involving incompressible air forces have been made on an analog computer. A wind-tunnel investigation of one case having free play in the torsional degree of freedom has been made, and good correlation between theory and experiment is shown. The results indicate that the stability of a nonlinear system is highly dependent on the magnitude of initial displacements of the system from equilibrium. It is shown that in many cases the flutter speed is decreased by increasing the initial disturbance. The results also indicate that, when a nonlinear system becomes unstable, its flutter may become self limited.

The influence of sweep on flutter was reviewed and discussed in a paper, "On the Flutter of Swept Wings," by P. F. Jordan. On the basis of comparative calculations, the paper discussed the relative merits of a number of methods of calculating the flutter speed of swept wings: the axis-normal approach developed in NACA Report 1014, the stream-parallel approach developed by the author in Germany and in England, and the effects on flutter speed of the rib direction and of using camber coefficients. The basis for the comparison is a new three-dimensional aerodynamic method. The paper also reported a tabulation of calculated flutter speeds for the wing with fixed root conditions and various parameter combinations including sweep angle, aspect ratio, Mach Number, axis positions, and mass ratio. Further, it discussed the effect of swept root conditions and of body freedoms and made comparisons with available experimental results.

Aeronautical Engineering Education

by
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Associate Professor
Aeronautical Engineering
University of Florida

The session on aeronautical engineering education had as its theme "Facts and Figures on Engineers' Progress." The first paper was presented by Dr. Allen O. Gamble, Head of the National Register of Scientific and Technical Personnel of the National Science Foundation and formerly Examinations and Standards Officer of the NACA in Washington. His topic was "Engineers' Progress in Research, and Why," and he began with a definition of research: "any systematic and persistent search, even though unsuccessful, for the purpose of making a discovery, theory, or invention, or of establishing or perfecting its validity or usefulness." This definition includes the accepted forms of research and excludes library search for existing facts, product testing toward acceptance or rejection, and other borderline areas.

Regarding the term "progress"—at one extreme it may be represented by complete failure, firing of the individual. It may range through transfer from research work, stagnation or slow promotion, faster promotion, notable achievements, and finally shining success. Five factors are found to bear on success in research: (1) generalization versus specialization, (2) fundamentals versus application, (3) research procedures, (4) working with others, and (5) vocational guidance and selection.

Success or failure in research is not strongly affected by college specialization. Successful individuals come from all fields of engineering specialization. The important aspects of college study seem to be primarily in the common elements among engineering and science curricula. College specialization must lag behind industry and research for a number of reasons. One of the commonest causes of failure in research work among young engineers is lack of mastery of fundamentals. Colleges could increase the emphasis on such things as physics, mechanics, thermodynamics, and other fundamentals that are least susceptible to change.

Training in research procedures will promote success. Six steps are suggested, leading to reporting of results: (1) recognition of a problem, (2) organization of existing data, (3) exploration of a solution and possible proposal of a hypothesis, (4) externalization of the hypothesis, (5) testing the tentative solution, and (6) evaluation. Colleges could help by encouraging understanding of such procedures and development of creativity. Working well with others is also important, and inability to do so has led to some research workers' failure at NACA.

A major reason for success or failure in research is the complex set of abilities, aptitudes, and personal characteristics of the individual as a unique person. Guidance is difficult along these lines because of lack of reliable measurement techniques. Some factors are an inquiring mind, fertility of ideas, originality of thinking, intelligences of several kinds, interest and enthusiasm, tenacity, critical attitude, and intellectual honesty. Not too much emphasis should be placed on classroom grades. Possible candidates for research should be noted and encouraged while engaged in academic pursuits.

In his paper entitled "Engineers' Progress in Industry and Why," C. C. LaVene, Engineering Employment

Manager of Douglas Aircraft Company, expressed the hopes of industry for young engineers with the ability and the will to be successful. One with necessary intelligence and aptitude can be trained for success, and the training should begin before the engineer enters industry. The employer should be able to help the educator in this matter, as progress or the lack of it is judged by the employer.

Progress potential is defined as that quality which causes a man subjected to a favorable environment to progress inexorably. An engineer so equipped works hard and effectively, assumes responsibility eagerly, adjusts easily to people and situations, and has an attitude of professional pride in the knowledge, supported by tangible evidence, that he is contributing to the organization in which he is working. The environment in industry is generally extremely favorable. Failure to progress may not be attributed to a single answer, but there are certain fairly consistent patterns in the failures.

There are three more or less distinct stages of career development facing the young engineer. The first stage involves a year or so in which the new employee seldom actually earns the dollar value of his salary. He learns company operation and demonstrates his work habits, his ability to take direction, and his care and reliability in performance of work. For many, new habits must be formed. The second stage follows this "training period," and the company will push the engineer into more independent work. He must ferret out information for himself. He should be able to work without too much supervision and must be able to present his findings clearly in verbal, written, or pictorial form. This ability of presentation is an area of *great* neglect. If men do not accept responsibility, they do not progress and are in effect high-priced computers which the company cannot afford. Men successful in this second stage of development may qualify as senior engineers or lead-people.

The third stage requires that the engineer develop necessary skills to manage and direct the efforts of others. This is the level which industry would like larger numbers of engineers to attain and appears to be particularly difficult for many technically trained men. Engineers who fail to progress through these three periods of career development are hampered because they lack understanding of human relations. Rarely are engineers from reputable schools inadequate in technical training, but chances of success are rather small unless such training can be correlated with nontechnical abilities, with a balance of imagination and judgment. If an engineer has aptitude for engineering; broad fundamental technical training; ability to do things in the most expeditious manner; initiative, requiring no prodding; an objective view of ideas and work; and a keen appreciation of the value of teamwork, he should progress through the three stages.

Recommendations for the educator include reviewing and altering standards as needs change, practical application of fundamentals in an atmosphere as nearly industrial as possible, integration of courses for maximum benefit, greater emphasis on self-expression, emphasis on purposeful extracurricular activities, and development of imagination of students. In support of his paper, Mr. LaVene presented some actual cases of poor progress from engineering personnel records, with supervisors' comments.

"Educating Engineers for Progress" was the topic of a paper by Prof. Dwight F. Gunder, Head, Department of Engineering Mechanics and Materials at Cornell University. His opening remarks reflected that progress should be the aim of the education of engineers. He suggested need for improvement of the teacher, the subject matter, the presentation, the prospective student, the literature, and the "consumer."

In improving the teacher, stagnation prevention is suggested as the greatest single problem. This may be avoided through consulting, summer employment, and university research, but the teacher should also constantly continue his own education by increasing his facility with fundamental mathematics and sciences and with new developments. Too often he actually slips backward until—for example—he actually knows less calculus than his students, a fact which becomes evident in his teaching and in his textbooks. Subject matter should be *improved*—not necessarily increased. Courses should be reviewed to see what parts may be dropped to make way for a more thorough understanding of basic principles and their applications.

The presentation of subject matter is probably the area offering the greatest possible improvement. It is suggested that the beginning engineering student might be introduced at once into engineering courses where he can be taught basic mathematics, physics, and chemistry which he needs as he needs them and where he sees their application. Formal courses in these subjects could be taken later in the undergraduate program when he is in a position to understand, appreciate, and profit by such instruction. Such an approach has been tried experimentally, and students were found to assimilate advanced concepts with apparent ease at freshman levels. For example, calculus can be learned through application to problems and experiments without the student being frightened by the name or the mathematical approach. This idea has great possibilities but requires a liberal understanding view by college administration.

The current prospective student is probably better prepared in an overall sense than one of 30 years ago, popular opinion notwithstanding. It is suggested that the colleges and universities make little effort to adjust their programs to any real or fancied change in the preparation of entering students.

The improvement of literature might be accomplished through reduction of the volume of engineering matter published. This, in turn, might be accomplished by the condensation of those papers which might be called routine solutions of more or less standard problems and the expansion of the current form of presentation of

(*Continued on page 88*)

The 20-jet-engine, million-lb. cargo air monster.

The Economics of Large Aircraft

A discussion of the feasibility of carrying fighter planes, missiles, and bulk cargoes by air rather than by sea.

Grover Loening*

THE ADVENT of turbojet engines for aircraft has materially changed all concepts of the future possibilities of water-based aircraft or seaplanes as we had known them.

The basic parameters of old seaplane design, particularly of the flying boat category, have always been adversely affected by propellers and requirements for clearance from spray. A whirling propeller at 1,800 r.p.m. or more, with the tip speed approaching the speed of sound, is hardly a practical item to put into contact with water. As a result, flying boat design inevitably became clumsy, high off the water, awkward,

Presented at the IAS Philadelphia Section meeting, Jan. 4, 1956.

* Consultant.

and with higher parasite resistance than equivalent land planes with folding landing gears.

Since slow aircraft—for almost no matter what usage—never survive to any *general* usage, we have seen water-based aircraft go out of the commercial picture. There were, of course, additional reasons, which we should note here: (1) more costly maintenance (particularly because of corrosion), (2) expensive and undeveloped means of handling at suitable docks, and (3) generally heavier construction required, because in the earlier days we had not devised design features that would allow operation in rough water.

All of these adverse features have been, or are in the process of being, overcome. New metals (notably titanium and alclad), new finishes that resist salt water corrosion, and new and easier accessibilities have greatly reduced maintenance. New means of handling and docking flying boats have been developed to a high degree. New hull designs of high length-beam ratio and the use of sprung skis to take initial water impacts at high speeds have all reduced the weight of hull necessary for rough sea take-off and landing. We have one more added feature now being developed for this department, and that is a vast improvement of high lift for landing and take-off, almost in the vertical category, by new designs, producing artificial airflow over the wing at slow speeds from the energy of turbojet power plants. In fact, the advent of the "jet flow wing," with a forced circulation in the slow speed regime to give greatly reduced take-off distances and greatly reduced landing speeds, will still further reduce the stresses on the hulls due to waves and thus lead to a quite lightweight hull structure.

It is clearly in the books therefore that shortly, if not right now, water-based aircraft will be lighter and cheaper than land-based aircraft, in particular because of the total elimination of the landing gear. Let us not forget that the landing gear is an item of somewhere between 6 and 12 per cent of the weight of an aircraft, that it is carried around all through the life of an aircraft as a dead weight and merely used for a few moments when landing and taking off, and that it is of no use whatever to the over-ocean aircraft when making a forced landing—whereas the hull is always there to serve its purpose. When "bleeding" from a jet-engine source on a seaplane is used to break the water suction at the step and at other places on the hull during take-off, the distance of take-off and the power required on a water-based aircraft is considerably less than would be required to overcome the rolling friction of wheels on a land-based aircraft.

Since water-based aircraft therefore are far from passé—in fact, quite the contrary—we can approach a new area in appraising their possibilities. In extremely small business and personal plane sizes, independence from airports is gained because any water area or lake is a private airport. In medium transport sizes, such as represented by the range from Convairs to Douglas DC-7's and Constellations, the terminal facilities are now so well organized that there would be no particular merit to water-based operation, except in those cities where docks for water-based aircraft would be more convenient than distant outlying airports.

But note that the size of aircraft is ever increasing; also note that the number, expense, and complex designs of ramps and loading equipment are beginning to become as expensive items of operation as a dock for a vessel. (In fact, a new era is now opening for actual air docks.)

So we seem to be approaching an era where we can give a really good look at size in aircraft, the economics of size, and what types really big aircraft are likely to become. In a short 20 years, the bombers, which have had the greatest development in the aircraft business, have increased in size from an original 40,000 to 400,000 lbs., almost ten times as big. Thirty years ago, a 20,000-lb. aircraft was a big one. Let us face up to the facts. Statistics show that we are going to go into aircraft reaching in size to millions of pounds within the next 20 years. An important mark of progress to keep in mind, also, is that the larger aircraft are also the faster aircraft. The Douglas DC-8 and the Boeing 707 are already almost three times as heavy as their predecessor Constellations and DC-6's and, incidentally, are twice as fast.

We need not burden this study of the possibilities of larger aircraft by too many detailed figures on how ever-larger aircraft will constantly be more efficient and give transportation at a cheaper rate. When the weight of the aircraft is doubled, the size of the pilot is not doubled, nor are the size and weight of the seat he occupies nor the weights of the instruments. Since doubling the weight presumably doubles the load, the law of the cube enters into the volume involved, so that doubling the volume does not require doubling of all dimensions, with a doubling of parasite resistance. Therefore, the relative efficiency of really large aircraft benefits from size all around, because we get greater efficiency from the higher Reynolds Number on the wing, a lower parasite drag per pound of load carried, a relatively lighter weight of all that has to do with crew, instrumentation, and installations, and so on.

If therefore we are to become interested in a 3-million-lb. aircraft carrying 1 million lbs. of cargo, let us realize that, at least at the present time, the simplest way to achieve this would be by a water-based design. This would be particularly appropriate since such a large aircraft would probably be used in carrying cargo loads over the oceans. Instead of charting tables and graphs that will change with changes in engines, fuel consumptions, etc., let us get a picture of this problem by looking at two versions of a large flying boat—one, for the military, a flying aircraft carrier, discussion of which must be surrounded with considerable security restrictions; the other, which we feel much freer to expand on, a cargo carrier of sufficient size to equal the cargo transported in a year by a C-2 ship freighter. When we have arrived at the general layout of this size, we can study what we are up against in relative cost and can study what happens when new things are developed, like

nuclear energy power plants. First, then, let us look at the flying aircraft carrier.

Flying Aircraft Carrier

Supersonic fighter or bombing planes are at a great disadvantage if based on airports. There is a lower limit to their landing speed. The landing gear is a clumsy, heavy, useless item except for the landing operation and is becoming increasingly difficult to stow in the thinner wings and in crowded bodies of the smaller fast aircraft. As the speed of fighting aircraft increases into the Mach 2 region, the amount of power—and therefore the amount of fuel required—increases enormously, so that supersonic fighting planes must either be refueled for any extended range or must return to a base after a sortie. Long delayed efforts have finally been made to develop "parasite" aircraft such as the F-84 fighters that are carried slung under the B-36 bombers. This preliminary operation has been found to be a great deal easier than was expected. The supersonic planes of the X-1 and X-3 class have, of course, been launched in flight from the B-29's as a matter of necessity because of their short fuel range. When we add all these considerations together, we find that a flying aircraft carrier that could cruise at 40,000 ft. at 400–500 m.p.h. and would be large enough to accommodate a large number of supersonic fighting, attack, and bombing planes not only is a desirable design to study but is so feasible (based on the ordinary nonsecret technique of the day) that we had better get busy working on it, as a potential enemy could easily be doing the same thing.

For a first-hand preliminary look at what is possible along these lines, there is submitted herewith an ordinary hull, on classic lines—a monoplane design of conventional type but of a size suitable for housing twenty 12,000-lb. fighting aircraft. A suggested general layout of this design is shown in Fig. 1 and is, of course, subject to a great deal of change as the study progresses.

The total weight of this flying aircraft carrier is 2,200,000 lbs. For high performance a thrust of one-fifth of this weight is desired—namely, 440,000 lbs. By the time a development of this character has been under way, ordinary jet engines of 22,000-lb. thrust would be available. Twenty such engines, therefore, are required—ten for each wing.

Placed across the wing in this manner and with the wing so large that they can be well housed (minimum drag configuration), it becomes relatively easy to introduce the two desirable kinds of circulation control for efficiency. The first is a suction over the leading edge to reduce drag by extending the laminar flow area, and the second is a forced circulation over the wing flaps to reduce greatly the landing speed and take-off time. At a load of 110 lbs. per sq.ft., the wing area is 20,000 sq.ft. This loading is not considered too high for this large Reynolds Number and with boundary-layer control for added lift.

Since the top deck of this design is almost 300 ft. long, a fine platform for approaching and contact landing, and take-off, at 400–500 m.p.h. is offered—with the approach to the stern cleared by the twin rudder arrangement shown with a span of 80 ft. between the two rudders. The simplest type of tapered wing is suggested—a total span of 360 ft.—chord at the base, 80 ft.; chord at the tip, 40 ft.; with the trailing edge straight and the leading edge raked.

The tail is a normal configuration of stabilizer and elevator, with a span of 80 ft., carrying fins and rudder at the tips projecting below the stabilizer to act as effective fences for the airflow. This configuration enables the landing aircraft to have ample room to fly closely above and onto the deck for its contact landing.

Side floats are incorporated in the design, the mounting pylons of which could be used for armanent housing.

Excellent seaworthiness is provided as this carrier can land easily in ordinary open sea for refueling and resupply from surface vessels or submarines.

The handling of the fighting aircraft is subject to a great deal of design. A preliminary thought is to have an inclined trap door (with hooded cover separately hinged), as indicated in Fig. 1. This would be closed except to take aboard landing aircraft or to raise one to the deck for release. At the high speed of the carrier and with the ease with which the approaching aircraft can maneuver to the same speed for merely touching down, landing should prove easy, and take-offs would be almost instantaneous without any catapult. The fighter need have no landing gear, merely skids with engaging hooks, a track, or magnetic pads for a magnetized track to hold, move, and release the plane as desired. However, there are important difficulties to be met. For one thing, no crew can be used to handle the planes on the deck because of the high speed of airflow and turbulences, and, because of this speed, the landing or take-off aircraft must be held firmly until release is desired. In addition, no large amount of landing wires, fiddle bridges, or landing traps can be tolerated at so high a speed. Instead of a ramp, an airlock forward could be used for release, somewhat like a torpedo chamber. No doubt other ways would be found for handling the aircraft, but there must always be borne in mind the airflow turbulence, at 400–500 m.p.h. Operating a track or a ramp would probably require the equivalent of airtight locks as on a submarine, particularly as this operation is done at pressure requiring altitudes. For any maintenance work on the aircraft, the crew can don pressure suits, or the carrier can temporarily descend to a lower altitude, as pressurizing the entire hull is out of the question.

A preliminary study of the weights involved works out as shown in Table 1, page 52.

With coming improvement in chemical fuel consumption, reduction in drag due to improved "area rule" body configurations, and boundary-layer drag reductions, it is estimated that this aircraft could cruise slowly but at altitude, for 10 hours, using only 80,000 lbs. of fuel an hour with present types of engines. The multiplicity of jet engines helps here because, in slow-cruising regime, several engines can be shut down.

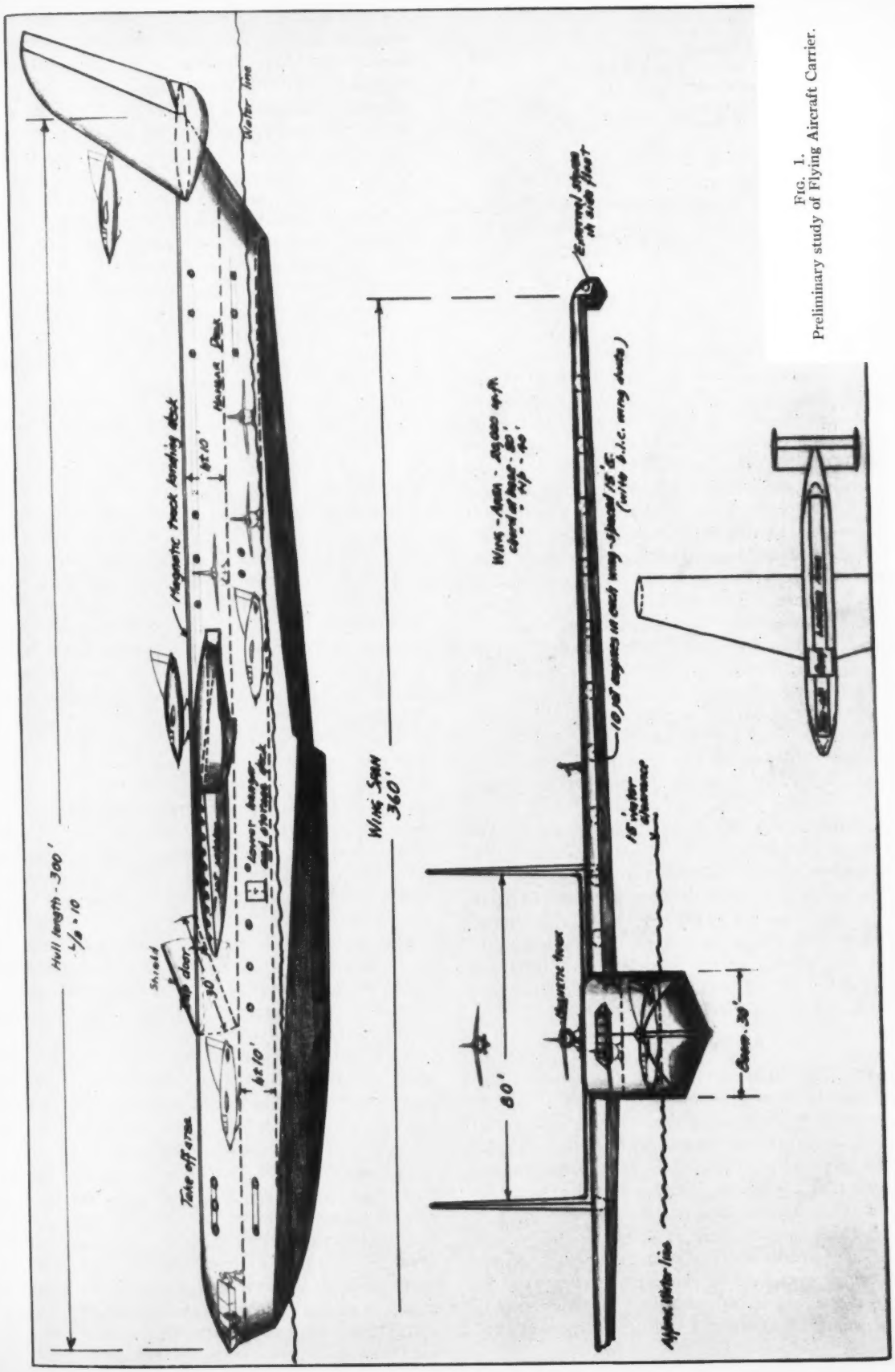


FIG. 1.
Preliminary study of Flying Aircraft Carrier.

TABLE 1

A military-equipped jet seaplane of this character will weigh about 40 lbs. per sq.ft. of wing area empty.	
The weight empty, including engines and installations	800,000 lbs.
Twenty 12,000 lbs. fully loaded supersonic rocket aircraft, including fuel, pilot, and bombs	240,000
Extra crew and their rations, 100 men at 500 lbs. each	50,000
Extra armament stores	50,000
Spare parts and extra equipment	100,000
Extra rocket fuel for five missions each, for 20 aircraft (1,600 lbs. per mission)	160,000
Fuel for the carrier	800,000
Total	2,200,000 lbs.

We have then an aircraft carrier with a lethal complement of fighting aircraft of the highest supersonic type which can stay aloft as a base for 10 hours, can fly all over the world—covering thousands of miles at high altitude—and can deliver supersonic aircraft into the air with the utmost range near a target under the most excellent conditions. Most importantly, we have a base for such aircraft to come back to, to be refueled and rearmed. In addition, operating at this high altitude, such a flying aircraft carrier has peculiarly fine qualities as a radar base for either detection, interception, or guidance. Actually, such a carrier need not launch manned aircraft. It could be used as a base flying at high altitude to launch guided missiles, thus reducing the missile's burden of a first-stage, ground-to-altitude booster.

Current cost of aircraft in extremely small production runs somewhere from $20 to $50 per lb. At the higher figure, the cost of this aircraft would be $110,000,000. A Forrestal-type carrier costs over $160,000,000.

The entire picture of a flying aircraft carrier of this class would change to one of the greatest importance when nuclear engines become a reality. Operation as a base at 40,000 ft. could be done for a week at a time! And this base—moving at 400–500 m.p.h., with always the best radar reception—would be far less vulnerable to missile destruction than the fixed land base (the real "sitting duck" of the missile age) or the submarine-menaced, slow aircraft carrier ship on the sea.

AIR FREIGHTER

A giant cargo carrier offers itself now as an interesting field of speculative study.

A seaplane flying boat design with a total gross weight of 3 million lbs. is not too far off the beam for an analysis at present. A landplane of this size would indeed be quite a headache, both as to landing gear and the airports to accommodate it.

Going this far up the scale in design size offers the interesting opportunity to study what such a craft could do in comparison to, say, the existing efficient C-2 freighter vessel, which has succeeded the Liberty and Victory ships in carrying the maritime cargoes of the world.

Let us take a look at the C-2. It is a freight-carrying vessel, about 500 ft. long, and has some 18,000 tons total displacement. It will carry a cargo of 9,300 tons to Europe and with that a fuel load of some 1,900 tons. Its cubic capacity is 540,000 cu.ft. for general cargo, which gives an allowable density of 34 lbs. per cu.ft. (quite high for aircraft standards). On aircraft cargo, densities of 5–10 lbs. per cu.ft. are generally accommodated. In other words, in order to use its full tonnage capacity in cargo, the C-2 vessel must be tightly packed with bulk cargo, consisting largely of commodities; when it comes to less dense cargo like crated automobiles, furniture, perishables, or fabricated items in crates, the full tonnage cannot find enough room. So, for purposes of comparison, we will average out a 9,000-ton cargo capacity per trip to the shores of Europe for this vessel.

The C-2 will cruise at about 15 m.p.h., and, if we take an average 3,600-mile trip from our Eastern seaboard to British, French, Spanish, or African ports, we find that a vessel of this character will do a round trip in about 28 days—including loading time—and will, with a little time out for storm delays and shipyard maintenance, average about eleven round trips a year. This means that the C-2 freighter will carry 100,000 tons to Europe and 100,000 tons back in a year's operation. In order to do this, a crew of some 40–50 men are required, so that the freighter, in addition to its load, has to carry lockers, bathrooms, food, recreation halls, and libraries, to say nothing of the bunks and the bed linen. While this crew could do a little maintenance work when under way, such as some painting, the facts are that the long number of days that they are engaged in escorting this cargo to Europe is a considerable economic drain on the profits which, as will be presently pointed out, a fast aircraft eliminates almost entirely. On such a trip, the C-2 vessel would consume about nine-tenths of a barrel of fuel per mile, which would work out to about 38 gal. of fuel per mile or 137,000 gal. of fuel per trip, or about 3 million gal. of fuel per year.

It is important to compare a year's operation in this study because the whole essence of the story is that the vastly greater number of round trips made by aircraft (even though the tonnage per trip is so much smaller) comes out to a formidable figure in a year's operation. Some 10 or 12 years ago, this was demonstrated conclusively in the vast Military Air Transport operation over the Hump from India to China, supplying far more in less time than hundreds of trucks, slowly plodding on the mountain roads, could possibly achieve.

As a matter of fact, this writer is proud of the fact that over 15 years ago he was able to predict and forecast an enormous future for air-cargo carrying at a time when almost everyone else, including air-line executives and some Government officials, had dismissed the possibilities as impractical. In fact, it is incredible to look back and realize that in 1941 the War Department deliberately cut down on the production of C-54s and Constellations on the theory that such aircraft had

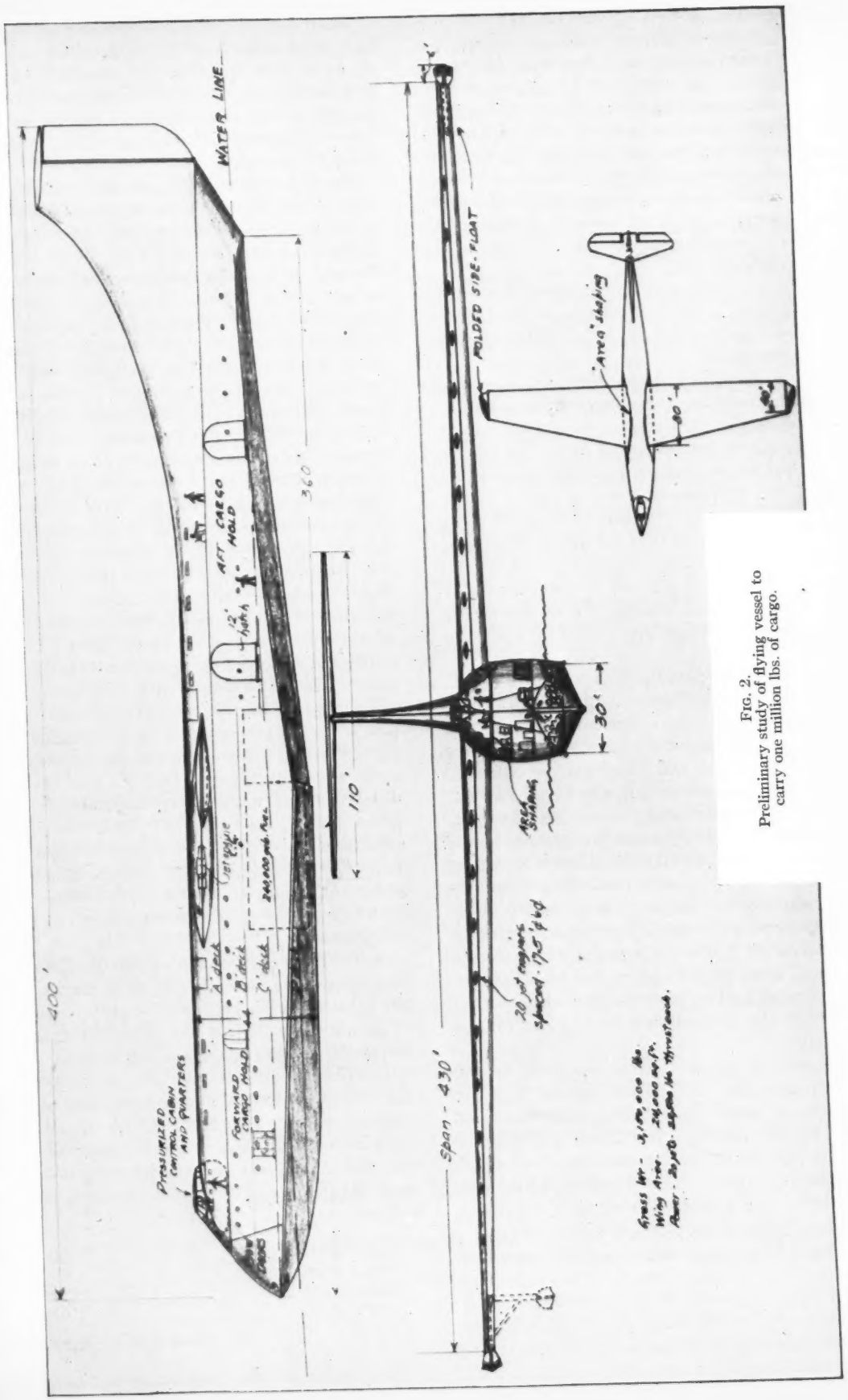


FIG. 2.
Preliminary study of flying vessel to carry one million lbs. of cargo.

no military value in time of war. War Production Board initiative, overriding the military decisions, and persistent pressure of a few far-seeing officers like Gen. Hugh Knerr, the late Adm. John H. Towers, Capt. Clarence Schildhauer, and several others, did much to modify the still-prevalent doctrine (now rapidly becoming out-of-date) that the object of air war was bombing—important as this was for "last year's" war. With the advent of the unmanned-air-vehicle-missile age, the importance of air transport in all sizes and in all military operations—air ground, or naval—is becoming increasingly vital.

Let us see what we might be able to look forward to in the top bracket of size and whether or not the economics of such a development are as hopeless as would appear at first glance.

The power plant for a 3,000,000-lb. cargo aircraft of the future in a seaplane version boils down to a turbojet or nuclear energy jet-driven type. Both the reciprocating engine and the turboprop fail to give us the two features so needed in this water-based design—the elimination of the propeller and the provision of jet-induced airflow over the wing and the body. Existing jet engines at the present time are passing experimentally from 15,000 lbs. thrust already obtained into the 20,000-lb. category, and it is not unreasonable to assume that in less than a decade, or even sooner than that, we will have efficient jet engines in production with 22,500 lbs. thrust.

Also, in the coming several years, drag will be still further reduced by the various airflow features now being developed, including extension of laminar flow over the wings, application of area rules at wing-body intersections, etc. This will reduce the power needed for cruising flight, and the wing flow and body flow features already discussed will reduce the power required for take-off. Whereas today, in order to obtain a speed of 600 m.p.h. at 40,000 ft., a thrust of at least one-fifth of the weight is needed, it would be reasonably safe to foresee that this will surely be reduced to about one-seventh of the gross weight for the same speed by the improvements that are now under way. It then follows, that, if we have 20 jet engines of 22,500 lbs. thrust each, we will get an allowable gross weight for the aircraft of 3,150,000 lbs., which is the figure we can use in this study.

A flying boat of this size, giving due credit for the higher Reynolds Number and the induced high lift wing flow would permit of an efficient wing loading of about 130 lbs. per sq.ft. (this has already been reached on some jet planes). The wing area, therefore, would be 24,000 sq.ft., which in the study shown results in a span of 430 ft. and a chord of wing with sweptback leading edge of 80 ft. at the base and 40 ft. at the tip.

On a 12 to 1 length-beam ratio, the 30-ft. beam hull would have a wetted length of 360 ft. The weights and dimensions of this suggested design, as can be seen from Fig. 2, are so close to the water level that relatively small retractable wing floats can be used, further reducing the parasite drag.

The size of the hull would allow of a four-deck version, as indicated in Fig. 2, with a total interior capacity for cargo of well over 100,000 cu.ft., which would give a density of 10 lbs. to the cubic foot when a million pounds of cargo are carried—an extremely favorable density compared to that of the C-2 ship, which is only one-third as roomy.

The fuel requirement is, of course, subject to great variation, depending on developments likely to come. At the present time, the best fuel consumption of a jet engine is about 0.8 lbs. of fuel per pound of thrust delivered. This is likely to be improved in the near future, at least down to 0.7 lbs. It must be remembered that the gas consumption of reciprocating engines used to be one-tenth of a gallon per horsepower hour, which amounted to about 0.6 lb. per horsepower hour, and yet today this has been reduced to almost half this figure. We can frankly admit that if a thrust-weight ratio of one-fifth, as of today, were not to be improved upon and a fuel consumption of 1 lb. of fuel per pound of thrust was the best we could hope to do, the fuel requirement of the nonstop flight on a plane of this size would use up almost all of the allowable weight. Our hope, then, would have to be placed in immediate new developments, such as the ducted fan engine, with which the fuel consumption would very likely go to half that of the pure jet engines per pound of thrust, *or in the advent of nuclear power plants.* But history shows that these figures are constantly being improved upon. The thrust-weight ratio of one-seventh is on the design boards, now, and a jet-engine fuel consumption of 0.7 lb. per pound of thrust is easily in sight. Using these figures, we arrive at the fuel requirements for 600-m.p.h. cruising with 10 per cent reserve for a distance of 3,600 miles, and cruising at 60 per cent total power. This gives a total of 1,250,000 lbs. of fuel or a total fuel capacity needed of some 200,000 gal. This in turn will require some 25,000 cu.ft. of gas volume which can readily be placed in this design near the center of gravity in an extremely practical and lightweight manner.

As for the weight of the aircraft itself, it must be remembered that this aircraft cargo carrier design is the lightest possible type because of the complete lack of military installations and complicated and heavy retractable landing gears and duplications needed in military work—and also the lack of pressurization in the hull, except for the crew unit indicated at the bow. Taking as a guide the weights of large-size aircraft that have already been built, it becomes reasonable to predict that this jet seaplane will weigh about 35 lbs. per sq.ft. of wing area. The weights, therefore, work out as follows:

Weight of aircraft	840,000 lbs.
Weight of fuel	1,250,000
Crew and extras	60,000
Weight of cargo	1,000,000
Total Weight	3,150,000 lbs.

Now let us see what such an aircraft could do. It

can fly to a European port with a 500-ton load in a little over 6 hours. Allowing 6 hours for loading and unloading, at each end, it can make a round trip in 1 day. Of the 365 days in a year, let us assume that as many as 65 days are used up in extra maintenance, overhaul difficulties, and weather delays. This would leave 300 working days or in other words, would allow this craft to make *300 round trips in a year*—which would give a total volume of loaded cargo of 150,000 tons a year, each way, which is 50 per cent more than is carried by the C-2 freight ship. This startling result is really food for thought, and we should, of course, look into the cost involved.

To begin with, an aircraft operation of this kind,with a short 6-hour flight, means that a crew of only five men is needed—pilot, copilot, navigator, radioman, and engineer.

These men do not need elaborate facilities of cabins, food, etc. All they actually need is a box lunch and toilet facilities. The actual figures on the economics of this operation are difficult to estimate because we do not know clearly the enormous savings that would result (as have already been indicated in air-cargo operations) in insurance, in crating, in eliminating the need for preserving perishables, and in various other expenses that have to do with shipping a cargo—items of cost entirely over and above the cargo rate. We do know that the actual expenses of the jet plane operation as against the ship are, of course, much greater in fuel cost. The freighter will use 3 million gal. of fuel per year. The aircraft will use 200,000 gal. of fuel per trip, which means 120 million gal. per year for the operation, almost 40 times as much as the C-2 freighter. All the possible savings in insurance, crating, delays, etc., would help to offset this. Most of the other items in the comparison between the plane and the ship more or less balance out, except that the initial cost of the aircraft is ten times that of a new vessel. However, on a pound basis, this difference works out to a fraction of a cent a pound on a 20-year depreciation, and the many economies, such as the economy of the much smaller crew cost, help to offset this. There is hope in the future on the fuel cost not only in new chemical fuels that are being developed to give power for much less weight but also in the lesser fuel used by the development of ducted fan engines. Also, finally, there will be the nuclear energy engine, which would solve this problem. It is certain that the extra weight of shielding needed for the crews' quarters and to surround reactors could not possibly weigh nearly as much as the fuel requirement in the jet-engine configuration.

If we could only halve this jet fuel weight by some of these new developments, the air load carried would be increased to 240,000 tons a year. The C-2 freighter fuel will cost about $250,000 a year, and the aircraft fuel would total $6,000,000 a year. But the C-2 freighter carries only 100,000 tons a year and the aircraft 240,000 tons. So the ship fuel costs $2.50 a ton and the aircraft fuel $25 a ton carried. Can this 1.125 cents a pound difference be offset by crew savings, less crating, less insurance, quicker deliveries, no refrigeration for perishables, less inventory carried, etc.? If not, let us go to the nuclear power plant in a hurry.

We have, therefore, an interesting preliminary study pointing to the great possibility of building an aircraft that will carry bulk cargoes at extremely high speeds over the oceans. With the advent of many new developments, it is possible to foresee that cargoes, even of such prosaic commodities as coal and wheat, could be carried *more efficiently and more cheaply by air than in the slow, plodding, ocean-going ships* now in use.

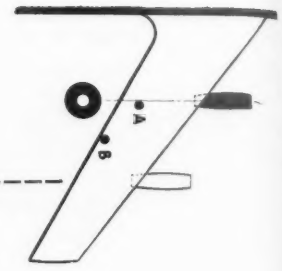
Of course, in time of war, the development of an air vessel of this character would have assumed enormous importance because the load capacity available would allow the movement of 5,000 troops at a time to the shores of Europe, Hawaii, or South America, or even, for that matter, across our own country. This is the kind of national military air power—added to missiles of long range to do the old bombing work—that may win the next war, largely by massive air envelopment. In this case, as in so many instances in history, a nonglamorous but courageous and ambitious development of commerce may give the strongest sinews for defense.

Last Call for Roster Listing

All members are reminded to send in their completed Roster Data Cards if they wish to change their listing in the next edition of the Roster. Members whose names do not appear in the 1955–1956 Roster are especially urged to return their cards immediately.

Those members not returning the data cards will be listed by repeating the entry (as of May, 1955) that appeared for them in last year's Roster. This is your last opportunity to be correctly listed in the 1956–1957 IAS Roster.

Holden W. Withington*
Boeing Airplane Company



Silencing the Jet Aircraft

The development of an engine sound suppression device that will reduce external jet noise with only a minor reduction in airplane performance capabilities.

Introduction

The general acceptance of the jet transport has been clouded by only one factor—noise. The Boeing Airplane Company has recognized that a successful jet transport must incorporate sound suppression devices that will reduce the external noise to a level comparable to, or lower than, present propeller-driven transports.

Many groups throughout this country and abroad have spent considerable effort on the reduction of jet noise. At the Fifth International Aeronautical Conference of the Institute of Aeronautical Sciences and the Royal Aeronautical Society, F. B. Greatrex reported on the work done on this problem at Rolls-Royce, Limited. John Tyler of Pratt & Whitney Aircraft Division, United Aircraft Corporation, has contributed several important papers describing work on this problem. The NACA has accomplished basic investigations in this field.

Making use of all available background information, Boeing embarked on a program to develop a noise suppression device for the 707 jet transport which would be the optimum combination of acoustical characteristics with minimum effects on engine and airplane performance and operation. This program involves three principal groups within the Engineering Department: acoustics, power plant, and aerodynamics. It includes several coordinated test programs:

(1) Model-scale acoustical tests.
(2) Model-scale thrust coefficient tests.
(3) Full-scale thrust tests.
(4) Full-scale 707 jet transport prototype noise tests.

Test Programs

This section of the paper will describe in some detail the various test programs in progress. In each case, the purpose of the test will be outlined and the apparatus described. Some discussion of the accuracy and types of result will be made. The findings of these test programs will be given in the section Discussion of Results.

(1) *Model-Scale Acoustical Tests*

One of the first steps in the overall program of developing a jet nozzle sound suppressor was to set up a small-scale facility which would be capable of acoustically testing a large number of different nozzle configurations quickly and at minimum cost.

The basic air supply available in the acoustical lab indicated that a maximum nozzle size of about 3 1/4 in. could be tested to pressure ratios equivalent to the J-57 take-off value. The actual size chosen results in a scale of 0.141 times the J-57 standard nozzle diameter. Fig. 1 shows a schematic diagram of the test setup.

Compressed air from the plant system is measured in the flow-tube, then heated to about 1,000°F. in the kerosene burner. The valve following the burner maintains sufficient back-pressure to ensure clean burning; valve and combustion noise is then reduced to an acceptable level by the straight-pass absorbent muffler. A gradual transition leads to the nozzle under test, and in the transition are located the total pressure and temperature probes.

As mentioned above, the scale factor for the model nozzles is 0.141 full-scale J-57. In order to correlate

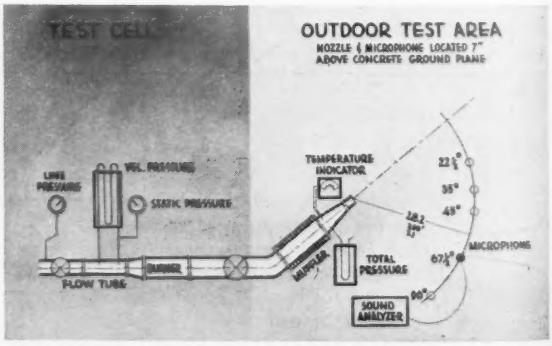


Fig. 1. Acoustic model test facility.

Presented at the Aircraft Noise Session, Twenty-Fourth Annual Meeting, IAS, New York, January 23–26, 1956.

* Technical Staff Engineer.

with full-scale testing, this factor is used throughout the acoustic setup to determine nozzle size and height above ground plane, microphone distance and height, and wave-length scaling. Since the scaled frequency corresponding to 10,000 cycles per sec. full scale is about 70,000 cycles per sec., good high-frequency response is required of the system, as well as good sensitivity to permit measuring relatively quiet nozzles; we therefore use a Massa microphone system fitted with a model 126 head (advertised as flat from 20 to 100,000 cycles per sec.), feeding a Spencer-Kennedy electronic filter good to 200,000 cycles per sec. for octave band analysis of the jet noise. (Although no absolute calibration is available for frequencies above the audio range, a small air-jet calibrator indicates that the system is probably reliable to something over 100,000 cycles per sec.). Two Hewlett-Packard vacuum-tube voltmeters are used—one as a preamplifier, the other as a sound-level meter.

All model acoustical tests shown in this paper were made at full-scale pressure ratios and temperatures corresponding to maximum dry take-off power of the Pratt & Whitney J-57 engine (JT3C-4). The exit jet areas were held constant, thus the thrust values were consistent within the variation of thrust coefficients.

(2) *Model-Scale Thrust Coefficient Tests*

As in the case of the acoustical model tests, it was felt desirable to check thrust and weight flow coefficients on a model basis in order to study the effects of configuration changes without the problems of engine operation and matching, as well as the much greater costs of both building and testing the full-scale nozzles.

The standard power plant nozzle test rig which has been used for several years in nozzle investigations was used for these tests. Fig. 2 shows this setup diagrammatically. Here the nozzle inlet pressure Pp' was adjusted by means of the primary globe valve. This pressure was measured by means of a Vibratron transducer and a Berkeley Counter. The inlet bellmouth pressure ΔPp was obtained from a Meriam Manometer. Supply air temperature Tp' was determined by means of a thermocouple and Brown Recorder. Thrust was determined by means of a counterbalance scale and ring-gage, set up as shown.

The approximate 1.7-in. nozzle size used in this test setup gave a scale factor based on J-57 engine of 0.073.

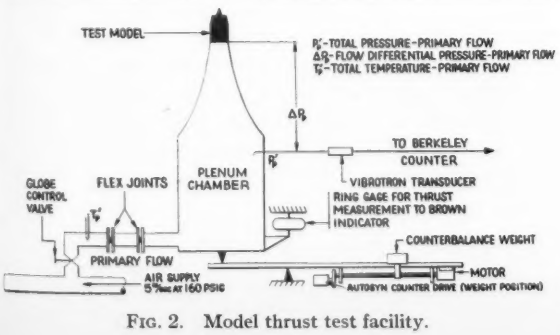


FIG. 2. Model thrust test facility.

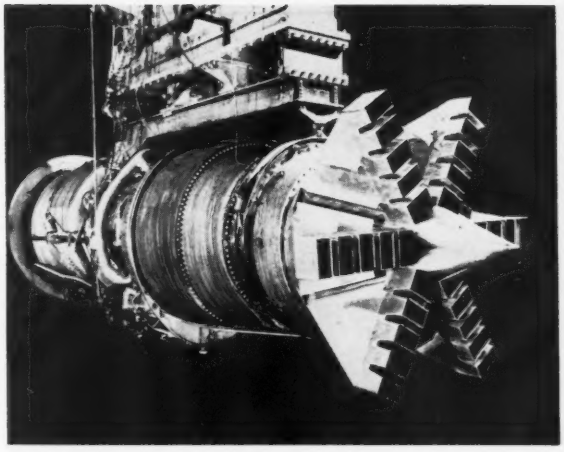


FIG. 3. Test cell installation.

Construction of models to this scale has proved to be especially difficult because of the extremely small size. Because of this, a new enlarged test facility is now being constructed to take the same size model as is used in the model acoustical tests. This will eliminate one of the scales from future tests by allowing the same model to be tested both on the acoustical and thrust measuring test setups.

(3) *Full-Scale Thrust Tests*

Full-scale tests were made on a test engine rig to determine the thrust, fuel flow, and engine operational characteristics with several noise suppressor nozzles attached.

Fig. 3 shows the engine hung in the power-plant engine test cell on flexures, the movement of which was restrained by a Baldwin-Lima-Hamilton 0 to 20,000-lb. load cell. The output from this load cell was registered on a Brown Indicating Potentiometer. To offset the unknown effect on thrust of secondary air passing over the engine, a bulkhead was installed across the engine test cell. The engine projected through this bulkhead but was not fastened to it. This measured projection area, times the differential pres-

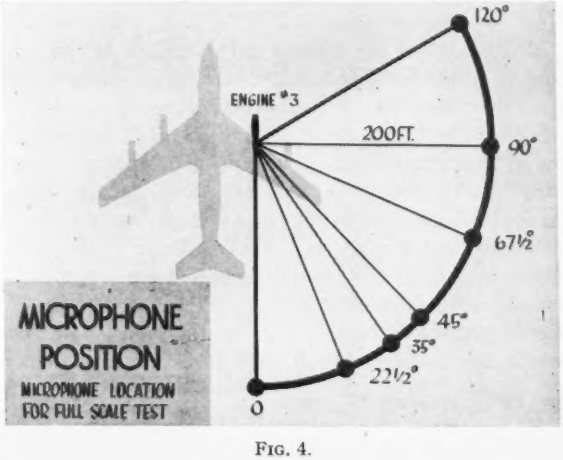


FIG. 4.

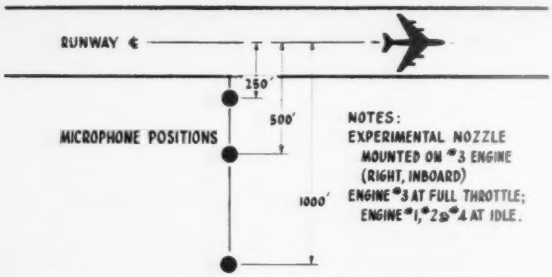


FIG. 5. Microphone positions for high-speed taxi tests.

sure across the bulkhead, was applied as a correction to the thrust.

A bellmouth inlet was used to eliminate inlet losses and was instrumented to measure engine airflow. Rotameters were used to measure fuel flow, and standard time-counter r.p.m. indicators were used to measure compressor speeds. Nozzle inlet total pressure and temperature were measured at four circumferential positions.

(4) *Full-Scale 707 Jet Transport Prototype Noise Tests*

The 707 prototype has been used to make two types of full-scale tests on the noise suppression development program—static and high-speed taxi. To date, these tests have been ground tests, although it is planned to conduct flight tests in the next few months on some of the promising configurations.

Fig. 4 shows a diagram of the airplane and the measuring stations used for the determination of the static noise patterns. Engine No. 3 was used for all nozzle tests. Fig. 5 shows a diagram of the measuring stations used in the high-speed taxi tests. These taxi tests were conducted by accelerating the airplane with four engines and then holding a speed of approximately 100 knots in the region of the test instrumentation, with the No. 3 engine at full take-off power and with Nos. 1, 2, and 4 back at idle. Runs were made with a standard nozzle on No. 3 and then with each of two noise suppression nozzles. Fig. 6 shows one of the configurations tested in these high-speed taxi tests.

DISCUSSION OF RESULTS

The results of the various test programs will be discussed in this section under the same divisions as in the preceding section. A comparison of model and full-scale tests will be made to show the areas of agreement. In addition, the effects of these noise reductions on the structural problems of the wing trailing-edge areas in the proximity of the jet exhaust is shown.

Throughout the report, each particular nozzle configuration carries the same designation number regardless of whether it is model or full scale. The prefix letters will indicate the scale and test program for which the model was built, as follows:

FS	Full-scale J-57 engine.
MAE	Model-scale acoustical (0.141 full scale).
MPP	Model-scale thrust characteristics (0.073 full scale).

Thus, FS 3 refers to nozzle configuration 3 full scale, and MAE 3 means that the nozzle configuration was 3 and that it was built to the scale for the model acoustical tests.

(1) *Model-Scale Acoustical Tests*

The use of small-scale model tests to check the acoustical characteristics has proved extremely valuable. Several configurations have been tested both model and full scale, and, although results do not check exactly, the data agree well enough to determine significant trends. A great many differently shaped nozzles may be tested quickly and inexpensively by this method.

The first series of nozzles tested, Nozzles 1 and 2, was taken directly from Dr. Greatrex's paper given at the 1955 IAS-RAeS meeting. The results are shown on Fig. 7. The data agree well with the Rolls-Royce work.

The noise reduction achieved in this first series appeared to be empirically a function of the periphery of the nozzle—the greater noise reduction being associated with the deeper corrugations or greater periphery at the nozzle exit.

With this in mind, several scale-model nozzles were made up which increased the periphery and to which many bars or wedges were added to increase further the turbulence in the jet exhaust. Figs. 8, 9, and 10 show the results. These figures show that rather large values of noise reduction can be achieved. A maximum reduction of 35 db. in the 75–600 cycles per sec. frequencies was obtained.

Fig. 11 compares the results of the above-mentioned model nozzles. This plot gives the noise levels at approximately the angle of maximum noise intensity. It should be noted that the majority of the nozzles achieved reductions in the frequency range up to about 2,400 cycles. Only one configuration, nozzle MAE 14A, Fig. 9, achieved significant reductions up through 9,600 cycles per sec.

(2) *Model-Scale Thrust Coefficient Tests*

The thrust characteristics for a range of pressure ratios of some of the noise reduction nozzles are given in Fig. 12. This figure shows that Nozzles 1 and 2 show essentially no loss up to pressure ratios of 2.5, then fall off to a loss of approximately 1 per cent at a pressure ratio of 4. Nozzles 3, 4, and 5 show fairly flat characteristics over the range of pressure ratios tested.

One cause of these poor thrust coefficients appears to be the fact that, when the corrugations extend down to the center plug, separation occurs from the surface of the plug. Previous tests on this type of nozzle show that this will account for about 2 per cent or nearly half of the loss. The results of these tests show that more refinement is necessary to reduce the thrust losses associated with these nozzles.

(3) *Full-Scale Thrust Tests*

Five nozzle configurations were tested in the power plant unit's test cell to check actual thrust and fuel-

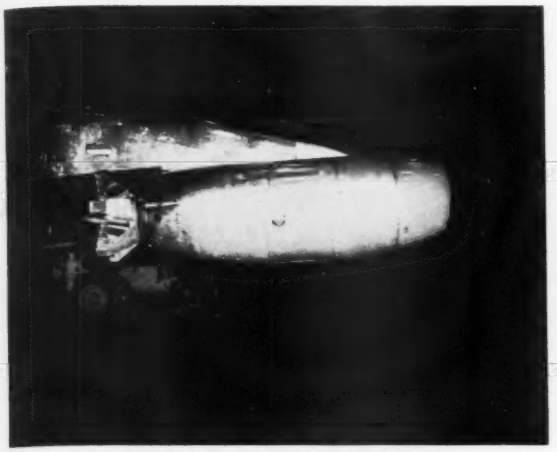


FIG. 6. Experimental nozzle mounted for high-speed taxi test.

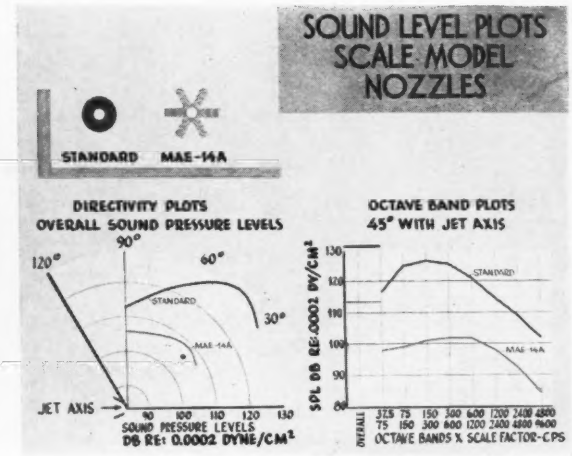


FIG. 9.

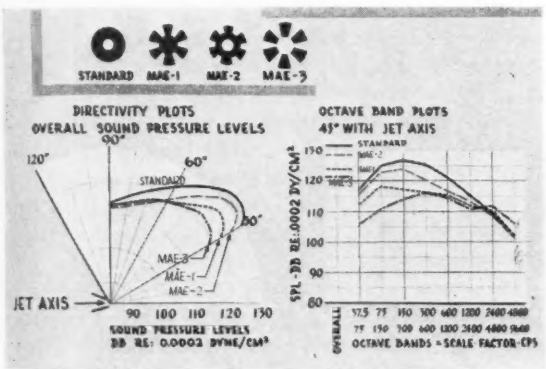


FIG. 7. Sound level plots for scale model tests.

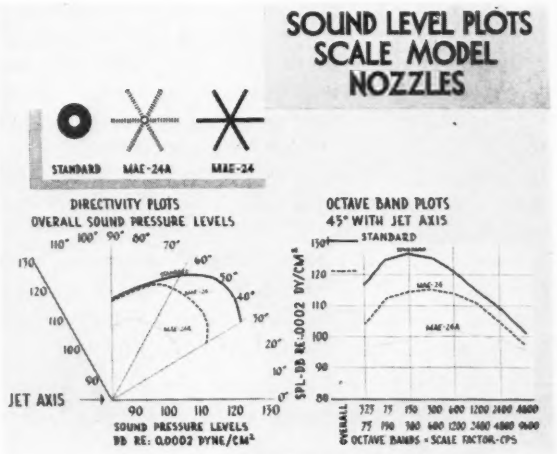


FIG. 10.

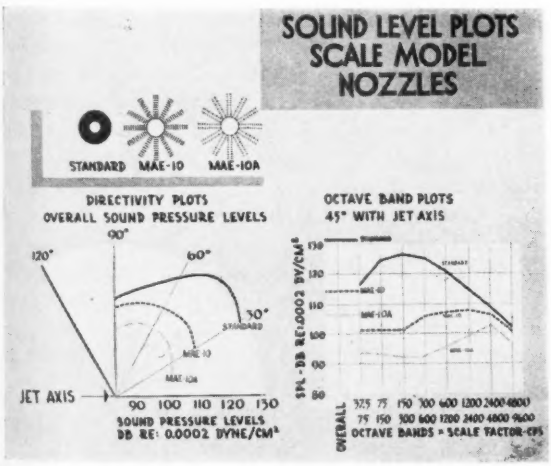


FIG. 8.

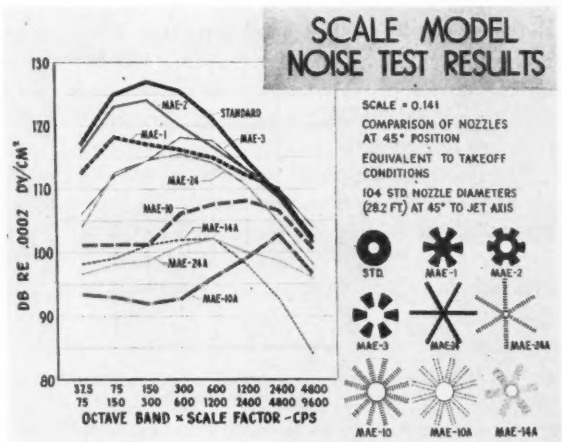


FIG. 11.

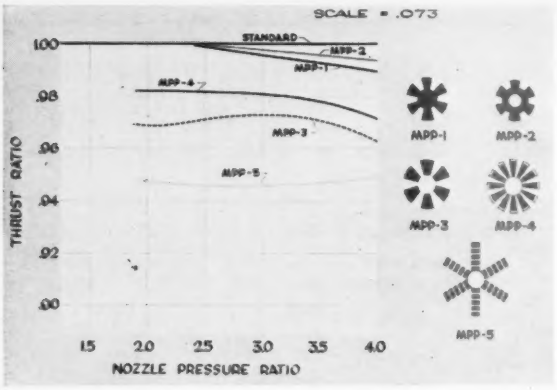


FIG. 12. Results of scale model testing.

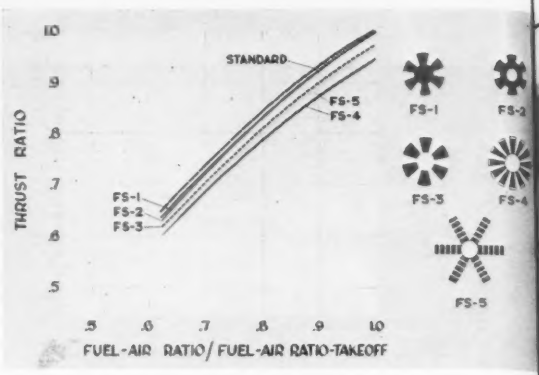


FIG. 13. Results of full-scale testing.

flow values and to determine the extent of the engine operating problems. The effects on thrust and fuel flow of these various nozzles as compared to the standard nozzle are shown in Fig. 13. From this we see that Nozzles 1 and 2 show extremely little effect. Nozzles 3 and 5 start to show a measurable deterioration. Nozzle 4 shows nearly 6 per cent loss. Further investigation of Nozzle 4 showed that the entire plug was separated. This is responsible for nearly half of the 6 per cent loss. We believe that it is entirely possible to eliminate this separation by proper plug shape and tailoring of the nozzle shape at the plug. Additional nozzles to correct this deficiency are now under construction.

Nozzles 1, 2, and 3 did not alter the engine match or operating conditions by any measurable amount. Nozzles 4 and 5 showed some mismatch which would require minor changes in exit area not exceeding 1 per cent.

(4) *Full-Scale 707 Jet Transport Prototype Noise Tests*

Two types of test have been conducted on the 707 prototype. One was the testing of seven full-scale nozzles on No. 3 engine for the purpose of measuring the static ground noise pattern in comparison with the standard nozzle. The second type was a high-speed taxi test to measure noise levels from a moving source, up to 100 knots. Two of the more promising noise reduction nozzles were tested in comparison with the standard nozzle.

The results of the static tests are shown in Figs. 14, 15, and 16. These data show reduction in the maximum noise values up to 15 db. overall and 20 db. in the lower frequencies. The greater attenuation of the low frequencies is encouraging as this means that, at greater distances, the overall noise values may show even more reduction because of the somewhat greater attenuation of the remaining high frequencies with distance. In addition, any shelter or airport building will give a greater attenuation to these remaining high frequencies.

We all realize that the static pattern is only part of the picture. There is much interest in the noise observed at a given point as the airplane passes by or overhead. It is possible to calculate by simple geometry what this noise level should be from a passing noise source, provided the actual shape of the noise contours are known. The standard conical nozzle gives a static noise pattern with the maximum at an angle of 35° to 40° from the jet axis. This results in a maximum noise level computed to occur as the moving airplane reaches a position where the angle from the jet axis is approximately 40°. This agrees with measured data from our high-speed taxi tests which showed the maximum at about 38°.

Most of the noise reduction nozzles tested to date in the Boeing program have achieved maximum attenuation in the direction of maximum noise which is from 35° to 45° from the jet axis. This results in a noise pattern whose shape is more nearly circular than that of the conventional conical nozzles.

From this, we would expect that the maximum noise level from a moving source, with the noise reduction nozzles in place, would occur at a somewhat greater angle from the jet axis and that the noise reduction would be less than that observed in the static pattern. The high-speed taxi tests run at Boeing tend to show this to be true, as shown in Fig. 17.

The results from these taxi tests are extremely interesting. Nozzle 5 had shown a maximum overall reduction of 15 db. at an angle of 40° from the jet axis. The taxi tests show a peak reduction of 10 db. and an average reduction of about 8 db. with two peaks, one when the observer was directly abeam of the airplane and the other at about 45° from the jet axis. This does not appear to be a poor measurement as observers noted this same characteristic by ear. No explanation is presently available. Nozzle 4A behaves more nearly as would be expected, with the peak reduction going from 15 db. in the static pattern to 13 db. in both peak and average values in the taxi tests. This peak occurred when the airplane had reached a position where the angle to the jet axis was 45°.

We can conclude from these tests that the noise reduction for this type of nozzle, as observed at a point with the noise source moving at speeds on the order of 100 knots, is approximately two-thirds of the maximum measured in the static pattern. This effect has been used in predicting the take-off and climb-out noise

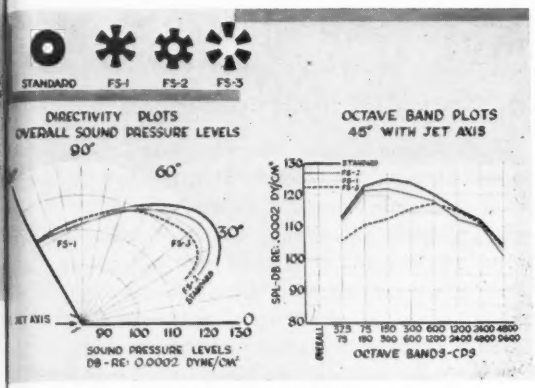


FIG. 14. Sound level plots of full-scale nozzles.

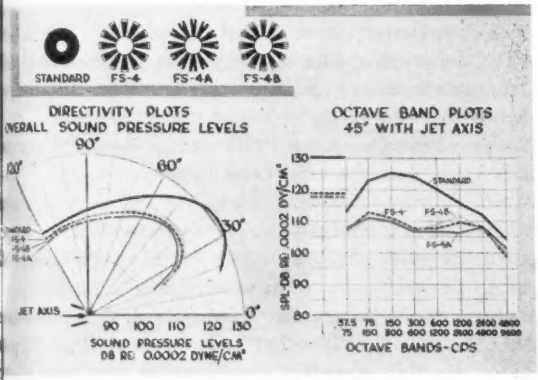


FIG. 15. Sound level plots of full-scale nozzles.

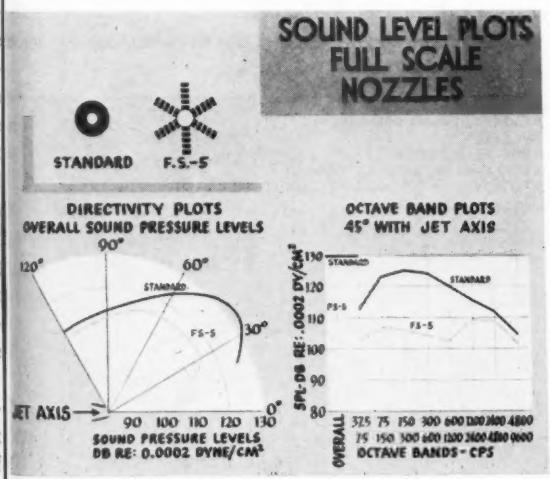


FIG. 16.

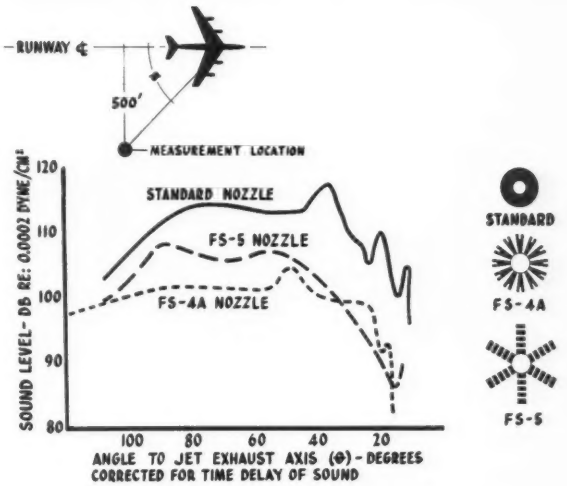


FIG. 17. Sound levels during high-speed taxi.

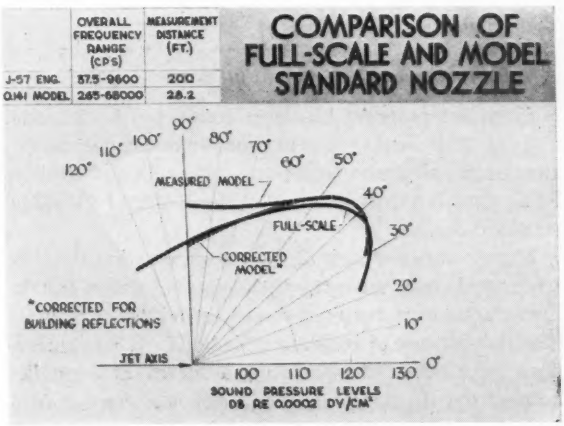


FIG. 18.

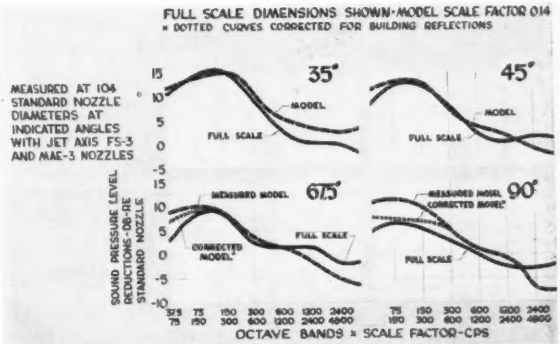

FULL SCALE DIMENSIONS SHOWN-MODEL SCALE FACTOR 0.14
* DOTTED CURVES CORRECTED FOR BUILDING REFLECTIONS
MEASURED AT 10.4 STANDARD NOZZLE DIAMETERS AT INDICATED ANGLES WITH JET AXIS F.S-3 AND MAE-3 NOZZLES
35°
45°
67.5°
90°
MODEL
FULL SCALE
MEASURED MODEL
CORRECTED MODEL*
SOUND PRESSURE LEVEL REDUCTIONS-DB RE STANDARD NOZZLE
OCTAVE BANDS × SCALE FACTOR-CPS

FIG. 19. Comparison of full-scale and model sound pressure level reductions.

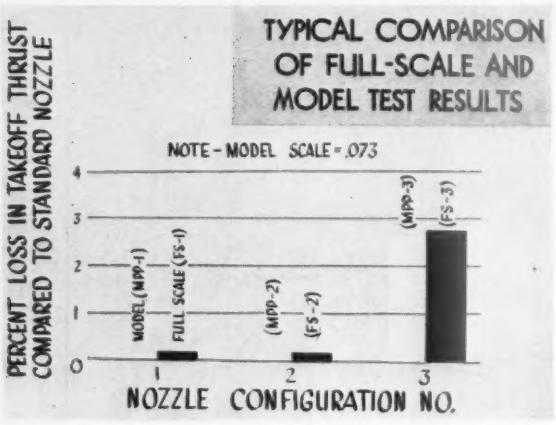


FIG. 20.

patterns of the 707 jet transport, as shown in the next section.

It is only fair to point out that these tests were made on the last day of a particular flight period and that the weather was unusual for Seattle in December—raining heavily with cross-wind gusts up to 25 knots. This may have affected the accuracy of the noise measurements of these high-speed taxi tests.

(5) *Comparison of Model and Full Scale*

Since our program has been conducted both model and full scale, it is proper to show some comparison between equivalent configurations. Figs. 18 and 19 show an acoustical comparison of Nozzles 1, 2, and 3 and the standard conical.

These comparisons, while not exact, do show that the model-scale tests are certainly adequate to show trends. Corrections were required to the model data at angles near 90° because of building reflections. These corrections were obtained by making a survey at a smaller radius from the nozzle. Since there is at least a 10:1 cost ratio in both construction and testing, the model-scale work will continue to be extremely useful.

Fig. 20 shows the thrust comparison achieved on Nozzles 1, 2, and 3. A comparison of Nozzles 4 and 5 has not been shown because it was found that the construction of the full-scale and model nozzles differed in the detail at the plug. This has been found to be critical.

(6) *Structural and Weight Considerations*

No discussion of these noise suppression nozzles would be complete without some indication of the weight penalties which we might expect from some of these weird shapes. Obviously, these nozzles will weigh more than the simple conical nozzles now in use on nonafterburning engines. Our full-scale test nozzles weighed about 100 lbs. more than the standard nozzle. These were so-called "boiler plate" test articles. Also, they are not "qualified" and were not considered suitable for flight. Much development work is required to achieve a noise suppression nozzle with life equivalent to the simple standard conical nozzle. However, if completely variable afterburner nozzles with hundreds of small parts are successful at afterburner temperatures, we should be able to make one of these fixed noise suppression nozzles a practical reality.

On the positive side of the weight problem are the structural benefits which are experienced on the underside of the wing in the region of the jet exhaust. Fig. 21 shows reduction of 17–19 db. in the lower "structurally critical" frequencies (150–1200 cycles per sec.) at two positions on the wing. This reduction in acoustical excitation is equivalent to a thrust reduction of approximately 50 per cent. This results in a possible trade of lower wing weight or increased life and lower maintenance in these areas. Experience with the B-47 and the B-52 has shown that major structural problems caused by this acoustical environment exist in wing trailing edges, flaps, and ailerons.

In addition to relieving the structural problem of parts of the wing, these noise suppression nozzles will influence the amount of cabin soundproofing required for a particular cabin interior sound level. This effect is most pronounced in the take-off and initial climb conditions and in the aft portion of the cabin during cruise.

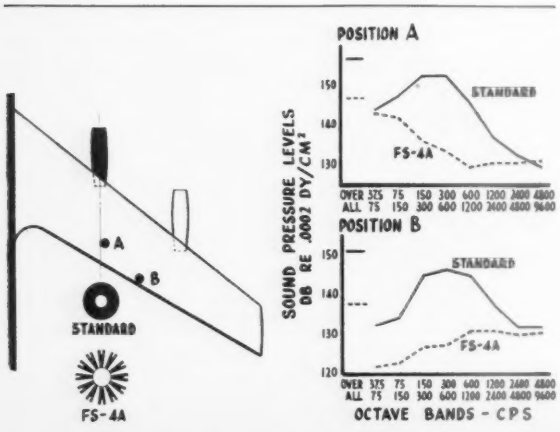


FIG. 21. Sound pressure levels—wing positions.

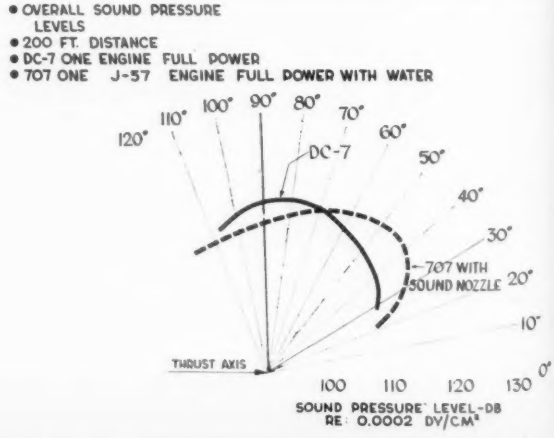

• OVERALL SOUND PRESSURE LEVELS
• 200 FT. DISTANCE
• DC-7 ONE ENGINE FULL POWER
• 707 ONE J-57 ENGINE FULL POWER WITH WATER
DC-7
707 WITH SOUND NOZZLE
THRUST AXIS
SOUND PRESSURE LEVEL-DB RE: 0.0002 DY/CM²

FIG. 22. Ground run-up comparison of DC-7 and 707.

Application of Results to the 707 Jet Transport

The preceding section has shown results in the various programs directed toward "Silencing the Jet Aircraft." The test program is far from completed, but we can see how the results obtained so far apply to the 707 jet transport. We will take the full-scale nozzle test data (4 and 5) as the basis for the configuration, keeping in mind that we have already achieved considerably more noise reduction in our model-scale acoustical tests.

Two problems are important: One is the ground run-up noise pattern, the other is the take-off and climb-out noise pattern.

Fig. 22 shows the ground run-up static noise pattern as compared to a typical propeller transport (DC-7). Here we see that the 707 jet transport will have equivalent maximum overall noise levels.

Fig. 23 shows the take-off and climb-out comparison between the 707 jet transport and the DC-7 propeller transport. We have compared the DC-7 with the 707 at gross weights which give the same range at maximum pay load. Use of the anticipated 9,500-ft. runway at New York International Airport would allow the 707 to be loaded still more heavily and hence achieve still greater range at maximum pay load. This would result in a flatter climb-out pattern and would increase by 1 db. the noise level on the ground at a point 2 miles from the end of the runway.

This figure shows overall values which are not necessarily a true picture of the annoyance. This is because the overall value tends to be determined by the low frequencies for the propeller airplane and by the high frequencies in the case of the 707 jet transport equipped with silencing nozzles.

Thus, from inside buildings, the jet will appear even quieter, and, in addition, the greater speed of the jet will mean less exposure time. The somewhat controversial factor of greater attenuation of the high frequencies with distance has not been considered in this comparison. This would mean still less noise annoyance for the 707 jet transport.

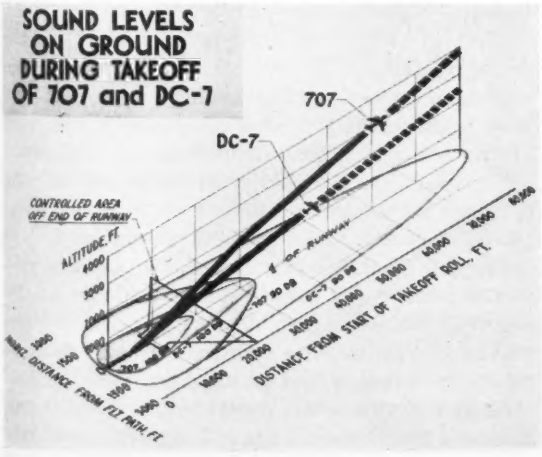


Fig. 23.

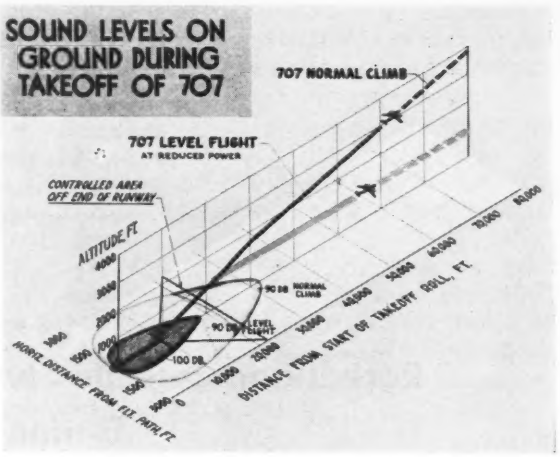


Fig. 24.

The preceding comparison has been made on the basis of a maximum power climb-out. This will tend to give the lowest total area affected by a given noise value. However, there are many airports which are surrounded by highly populated districts close to the field, but, several miles out, there may be open country or even water. In this case, it is possible to climb only to a minimum altitude of, say, 1,000 ft., then level off and reduce power until over open country or sea and then resume climb. This may result in a reduction for some of the surrounding areas. Fig. 24 shows a comparison of this technique with the maximum climb pattern.

Conclusions

The preceding paper is in effect a progress report of the jet silencing program currently in progress at the Boeing Airplane Company. It is an extremely encouraging report. Six months ago, there appeared little or no hope of reducing the jet noise with any remotely practical device; now, after only 3 months of actual testing with some seven full-scale nozzles and over 40 small-scale nozzles, we have been able to reduce the noise from the jet by amounts which could result in jet aircraft considerably quieter than present-day operating transports.

It is not possible at this time to predict the inevitable trade between performance penalty and noise reduction. However, even the present results indicate that we now have available to us a practical means of reducing the noise from jet engines. Further refinements will of course be required before the optimum combination of airplane and engine performance characteristics with the desired amount of noise reduction has been achieved.

It is logical to expect that the performance penalties and additional weight of the silencing nozzle will increase with the reduction of jet noise. However, the benefits of improved airport-neighborhood relations, the increased structural life of the wing trailing-edge

(*Continued on page 84*)

A summary account of the various stages leading to the development by the United States of the earth satellite program and a description of present plans and organization.

Rocket and Satellite Studies During the IGY

Joseph Kaplan*
National Academy of Sciences

THE SURGE OF INTEREST in the earth satellite program had its basis in the assemblies of some 40 nations, meeting to plan and integrate the unprecedented study of man's physical environment known as the International Geophysical Year, 1957–1958. This world-wide study primarily embraces those fields of geophysics in which observations must be conducted simultaneously over the earth if we are to achieve significant progress in our understanding of the earth and its atmosphere. Problems to be studied include aurora and airglow, cosmic rays, geomagnetism, glaciology, gravity measurements, ionospheric physics, longitude and latitude determinations, meteorology, oceanography, seismology, and solar activity. Two additional areas of activity are of special interest: rocket studies of the upper atmosphere and the recently announced satellite studies which represent a logical extension, technically and conceptually, of the rocket program.

The IGY program of the United States not only includes contributions to each of these fields but ranges far and wide geographically, into the Arctic and the Antarctic and into the oceans on each side of the Western Hemisphere. It will penetrate deep into the earth, ice, and oceans and high into the atmosphere, as well as above it. It will use the latest techniques and most advanced theories and, together with the data provided by the other nations, will provide research material for years to come.

The time for this major international effort was selected to coincide with a period of maximum solar activity. This will enable us to plan especially coordinated and intensified world efforts on such occasions as expected intervals of unusual magnetic, ionospheric, or auroral activity and on days of solar eclipses and unusual meteor showers. Special cooperative efforts will be made during these intervals to record the many phenomena which react so remarkably to the complex activities of the sun.

Since the satellite program is the one which is of special interest, I shall attempt to describe how it came into being, the present status of plans, and the types of experiment under consideration. Since the announcement of the program on July 29, 1955, by the President, questions on these points have been asked often by scientists and laymen alike.

The interest of the U.S. National Committee for the International Geophysical Year in earth-circling research satellites began with the adoption of resolutions during the summer and early fall of 1954, regarding the desirability of such vehicles. These resolutions were adopted by three international scientific bodies: The International Scientific Radio Union, the International Union of Geodesy and Geophysics, and the Special Committee for the IGY of the International Council of Scientific Unions (CSAGI). The resolution of most immediate interest is the one adopted on October 4, 1954, by the CSAGI:

"In view of the great importance of observations during extended periods of time of extraterrestrial radiations and geophysical phenomena in the upper atmosphere and in view of the advanced state of present rocket techniques, CSAGI recommends that thought be given to the launching of small satellite vehicles, to their scientific instrumentation, and to the new problems associated with satellite experiments, such as power supply, telemetering, and orientation of the vehicle."

In view of these international recommendations and in view of the advanced state of United States rocketry development, the Executive Committee of the U.S.

Presented at the Earth Satellites Session, Twenty-Fourth Annual Meeting, IAS, New York, January 23–26, 1956.

* Chairman, U.S. National Committee for the International Geophysical Year. Professor of Physics, University of California at Los Angeles.

National Committee for the IGY (USNC-IGY) considered the possibility of constructing, launching, and observing an instrumented satellite. A special group was established for this purpose, composed of various members of the USNC Executive Committee and the USNC Technical Panel on Rocketry.

On the basis of recommendations made by the special study group, the Executive Committee decided that an instrumented satellite program not only was of scientific importance but was feasible, and it adopted a resolution which reads in part as follows:

"The Executive Committee of the USNC-IGY feels that a small artificial satellite for geophysical purposes is feasible during the International Geophysical Year if action is initiated promptly and that the realization of such a satellite would give promise of yielding original results of geophysical interest."

The Executive Committee authorized me to transmit the aforementioned findings and resolution to the President of the National Academy of Sciences and to the Director of the National Science Foundation. This was done on March 14, 1955.

Meanwhile, the scientific and technical studies of the Committee's special satellite group continued. By the early part of May, a preliminary program had been developed, and the Committee directed me to transmit the proposed program to the federal Government through the National Science Foundation. This was done on May 6, 1955.

Late in July, the Government's approval of the satellite program permitted me to notify the CSAGI of our plans. In my letter of July 26, 1955, to Sydney Chapman, President of CSAGI and one of the world's most distinguished geophysicists, I said:

"The United States National Committee believes that significant scientific data may be gathered as a result of this program in such fields as geodesy, atmospheric physics, ionospheric physics, auroral physics, and solar radiation. The participation of other nations engaged in the International Geophysical Year is invited, and to this end we shall provide full scientific information on the orbiting vehicle so that other nations may monitor the device and make appropriate observations. The United States National Committee looks forward to the interest and cooperation of other nations in what it hopes will be one of the great scientific achievements of our time."

On July 29, 1955, Dr. Chapman released this letter to the public at Brussels through CASGI's Secretary General, M. Nicolet. A few minutes later, the President's endorsement of the program was made public at the White House by James C. Hagerty, the President's Press Secretary:

"On behalf of the President, I am now announcing that the President has approved plans by this country for going ahead with the launching of small, unmanned, earth-circling satellites as part of the United States participation in the International Geophysical Year, which takes place between July, 1957, and December, 1958. This program will, for the first time in history, enable scientists throughout the world to make sustained observations in the regions beyond the earth's atmosphere.

"The President expressed personal gratification that the American program will provide scientists of all nations this important and unique opportunity for the advancement of science."

Dr. Chapman replied to me on August 3, 1955. The substance of his letter is contained in the following three quoted paragraphs:

"On behalf of the CSAGI I wish to express great satisfaction that it was in consequence of the CSAGI resolution you quote that your National Committee arranged for a study of the possibilities and value of the construction of a satellite vehicle for upper atmospheric and other scientific exploration.

"I am glad to know that this study was so successful that your Committee felt able to resolve to construct and launch small satellites as a part of the United States contribution to the International Geophysical Year and to announce these plans publicly. The long experience of your scientists in rocket launching and construction, and the brilliant use they have made of rockets for upper atmospheric and solar exploration, gives confidence that the plans so announced will be fulfilled.

"This will indeed be one of the great scientific achievements of our time and will give occasion and opportunity for the cooperation of other nations in this outstanding part of the great enterprise, the International Geophysical Year."

These, then, were the early steps in the development of the Academy's satellite program: the international resolutions recommending such an effort; months of preliminary study and planning by the U.S. National Committee for the IGY, culminating in the March 10 basic recommendation of the Committee and May 6 program proposal to the Government; the exchange of letters between the Chairman of the USNC-IGY (July 26, 1955) and the President of CSAGI (August 3, 1955); and the President's endorsement of the program on July 29, 1955, signaling the actual undertaking of the program.

The scientific basis for the satellite program is to be found in the need for basic, directly observed data which ground-based experiments are unable to provide. The lack of such data is probably the most important single factor accounting for present incomplete explanations and theories regarding such fields as auroral and ionospheric physics.

Rocket soundings of the upper atmosphere have yielded significant results, and the IGY program includes a major rocket research effort. Some hundreds of rockets will be fired during the IGY, ranging from the relatively small balloon or aircraft-launched devices to high-performance Aerobees capable of reaching approximately 200 miles. The results of these experiments are expected to contribute to a better understanding of atmospheric events in two ways: (1) Rocket observations will provide direct data of various phenomena which can be used, so to speak, to calibrate

ground-based observations. The latter, as with ionospheric soundings, provide rather conveniently and inexpensively indirect data. (2) New discoveries may well be made, particularly of events screened by the earth's atmosphere.

Thus rockets permit us to make direct measurements of quantities that are either only indirectly observable or are not observable at all from the ground. They also provide a technique for measuring the altitude dependence of various geophysical parameters. Unfortunately, rockets have two serious disadvantages: (1) Their total flight is extremely short, and the time spent in a particular altitude range is even shorter. (2) Their flight paths are restricted in terms of geographic coverage.

Thus, in spite of the great value of rocket data, much of which is attainable only by rocket methods, there exists a need for a device that can provide synoptic data over the earth, at high altitudes, over appreciable periods of time. As examples, one can cite the following: fluctuations in such solar effects as ultraviolet radiations and X-rays, cosmic ray intensities, current rings encircling the earth, and particle streams impinging on the high atmosphere. These and other phenomena are among the most important problems connected with the physics of the upper atmosphere and with solar-terrestrial relationships.

Clearly an earth satellite would permit observations of the kind indicated, and the value of these studies convinced the USNC of the merit of responding to the invitation of CSAGI. In its report last October to CSAGI, the Committee indicated that the following types of experiments were under consideration: (1) determination of outer atmosphere densities by observation of the air-drag effect on the satellite's orbit; (2) obtaining of more accurate measurements of the earth's equatorial radius and oblateness and of intercontinental distances and other geodetic data than are presently available; (3) long-term observations of solar ultraviolet radiations; (4) studies of intensities and fluctuations in intensity of the cosmic and other particle radiations impinging on the atmosphere; (5) determination of the density of hydrogen atoms and ions in interplanetary space; (6) observations of the Störmer current ring; (7) if possible, determination of the distribution of mass in the earth's crust along the orbital track.

How many and what experiments will be undertaken cannot be specified at this time. In part, these depend on the number, size, and pay-load capacity of the satellites. In part, they depend on choices yet to be made by the USNC, in collaboration with interested scientists, for in all probability more experiments will be proposed than can be fitted into the IGY satellite program.

Work on technical details of the satellite is currently under way. Information now available may be stated briefly: The satellites will be small, will contain scientific instruments, will be trackable from ground by optical and radio techniques, and will probably be visible to the naked eye under optimum conditions at dawn and dusk and certainly observable under good atmospheric conditions by means of binoculars and wide-field optical equipment.

The satellite may be described as about the size of a basketball, although the shape has not yet been fixed. Each satellite will weigh more than 20 lbs. but probably less than 50 lbs. The satellite will travel about the earth in an elliptical orbit, with a perigee distance of at least 200 miles and an apogee distance of some 800 miles. It is expected that the satellite will remain in its orbit for at least several weeks and perhaps months. The greater the perigee and apogee distances, the longer the life of the satellite as a result of reduced atmospheric resistance. The velocity of the satellite will be approximately 18,000 m.p.h., giving a period of about an hour and a half, depending on the precise perigee and apogee values.

The Government's endorsement of the Academy's satellite proposal permitted the Committee to proceed beyond the preliminary plans outlined in its May 6 document. Whereas the studies of the Committee had been conducted on an *ad hoc* basis, calling upon members of the USNC Executive Committee and the Technical Panel on Rocketry, as well as upon various consultants, it now became appropriate to establish a Technical Panel on the Earth Satellite Program.

The membership of this Panel is as follows: R. W. Porter, Chairman (Consultant, Communication and Control Division, General Electric Company); Hugh Odishaw, Secretary (Executive Secretary, U.S. National Committee-IGY, National Academy of Sciences); Joseph Kaplan (Professor of Physics, University of California at Los Angeles; Chairman, U.S. National Committee-IGY, National Academy of Sciences); H. E. Newell, Jr. (Acting Superintendent, Atmosphere and Astrophysics Division, Naval Research Laboratory); W. H. Pickering (Director, Jet Propulsion Laboratory, California Institute of Technology); A. F. Spilhaus (Dean, Institute of Technology, University of Minnesota); Lyman Spitzer, Jr. (Professor of Astronomy, Princeton University); J. A. Van Allen (Professor of Physics and Head of the Department of Physics, State University of Iowa); F. L. Whipple (Director, Smithsonian Astrophysical Observatory; Professor of Astronomy and Chairman of the Department of Astronomy, Harvard University).

The functions of this Panel are analogous to those of the other twelve Technical Panels of the USNC in the various IGY disciplines. The Technical Panel on the Earth Satellite Program, with such additional membership and consultants as are necessary, will have fundamental responsibilities, acting on behalf of the USNC, in further developing, coordinating, and directing the overall scientific satellite effort. The Panel expects to utilize contributions from many scientists and institutions, a feature that has characterized the planning of all IGY programs under the auspices of the USNC.

At the same time, the Government's support made it desirable to begin certain technical phases of the effort immediately if launchings were to be realized as early as possible during the 1957–1958 IGY period.

The Committee had taken cognizance, in its May 6 proposal, of the need for logistic support from the Department of Defense; only through the use of this agency's facilities and rocket experience could the program be attempted economically and realistically. Accordingly, the Committee called for this type of assistance.

In making this request, the Committee had two major precedents: first, the Antarctic Program which requires extensive expeditionary and logistic support and, second, the rocket program. In both these areas, the Department of Defense has responded and is making substantial contributions to the IGY program.

Following the President's approval on July 29, the Committee's request for logistic support in the satellite program was granted. This support will be provided jointly by the three military services under Navy management. A group has already been established, directed by Dr. John P. Hagen of the NRL, for the conduct of Project Vanguard, the name assigned to Defense's effort. Contracts have already been issued for some of the propulsion rocket vehicles, and Project Vanguard will conduct the operations necessary to get the satellite on orbit, following much the same pattern established for the IGY rocket program.

The satellite program, then, is already under way. Although it is clearly an exciting and significant endeavor, one should not lose sight of the difficulties of the enterprise. The Committee's studies indicated that existing rocket technology provided a sound basis for the feasibility of the proposal. Yet the venture is truly a pioneering one, and partly for this reason the Committee's May 6 document called for some ten instrumented satellites, with the hope that at least five or six would be successfully launched into their orbits.

The growing realization of the technologic feasibility of a satellite endeavor in recent years provided the impetus to international considerations of such a program. The German V-2 rocket development of World War II, the high atmosphere research rockets—for example, the Aerobee and the Viking—of the United States, and related rocket efforts of other nations created a body of literature and a technology that provided the foundations for a new departure. During the last decade or so, the concept of small research satellites for the study of the high atmosphere has occurred to many thoughtful individuals. Members of the Upper Atmosphere Rocket Research Panel, an informal group of leading United States rocket and upper atmosphere scientists and engineers, have considered just such prospects.

Such, then, was the climate at the Rome meeting in the autumn of 1954 when representatives of various nations met to coordinate the IGY programs, and out of it grew the CSAGI resolution advocating the satellite venture. This venture not only has grown out of the world-wide IGY program but is a substantial and promising part of it. The intensity of effort to be devoted by more than 40 nations, investigating phenomena in some twelve geophysical disciplines, is augmented now by the results that the satellite program promises: observation of high atmospheric and interstellar events unhindered by the earth's lower masking atmosphere.

In this venture, other nations and other observers will share, for, as the President indicated, the satellite will be public. Its design and instrumentation will be made known. The frequencies of the telemetering system, which will radio back to earth the scientific observations, will be revealed. The results of observations will be published. These provisions, in keeping with the peaceful and cooperative spirit of the IGY, will permit the satellite to be followed and observed throughout its course about the earth.

One year after the Rome meeting and some 2 months after the President's announcement, the nations of the world met again at Brussels to integrate further their respective IGY efforts. The inspiring character of the President's announcement was clearly revealed. The scientists of the 40 or more other nations participating in the IGY received the news of the proposed U.S. satellite program enthusiastically. This reception was based in part on the great admiration by scientists of other countries for the past achievements of American rocket scientists. More important, however, this reception was based on the knowledge that the value of geophysical observations made during the IGY would be enhanced greatly by the addition of extensive, direct data obtainable only from research satellites.

Participation of scientists in this endeavor falls within the purview of the National Academy of Sciences, which established the U.S. National Committee for the IGY. This Committee, with its subcommittees and panels, is charged with responsibilities for planning, directing, and executing the United States-IGY effort. The Government has cooperated extensively in the realization of the program, both programwise and fiscally. The National Science Foundation, at the request of the Academy, has assumed responsibility for the fiscal aspects of the program and has played a major role in the coordination of Government interests. Federal funds totaling $12 million have already been appropriated for the overall IGY effort, and it is hoped that the current session of Congress will appropriate the rest of the funds needed.

An examination of the NACA research covering stability and control, propellers, and the aerodynamic characteristics of wing-propeller combinations, with a hypothetical design based on available information.

Problems in the Design of Propeller-Driven Vertical Take-Off Transport Airplanes

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Introduction

For the past 5 years the Langley Aeronautical Laboratory of the National Advisory Committee for Aeronautics has been conducting research on the problems of vertical take-off transport airplanes. Almost all of the work has been done with propeller-driven configurations, and the present paper will be limited to this type. The work has been based on the premise that such machines should be efficient airplanes with good flying qualities in the normal flight condition and should therefore be similar to conventional transport airplanes insofar as possible. Also, with transport airplanes, considerations of passenger comfort and cargo loading indicate the necessity of keeping the fuselage more or less horizontal at all times.

With these restrictions, two possible ways of achieving vertical take-off and landing come to mind. These are illustrated in Fig. 1. The top sketch shows a tilting-wing configuration in which the entire wing-propeller-engine combination is rotated to a vertical position for vertical take-off. With the other arrangement, the propellers, engines, and forward part of the wing remain fixed to the fuselage, and lift for vertical take-off and landing is obtained by deflecting the propeller slipstreams downward by means of large-chord flaps or vanes.

To evaluate properly the relative merits of these two schemes, it was first necessary to have some information on the type of configuration needed for deflecting the slipstreams. The first approach was to use a cascade of 90° arc turning vanes. Hovering, take-off, and landing flight tests of a model using four such vanes indicated that the deflected-slipstream principle could be used to obtain VTO performance.[1] These successful results led to two subsequent research programs. The first consisted of flight tests to study the stability and control problems in hovering and transition of two configurations—one utilizing the tilting-wing idea, the other employing the deflected-slipstream principle. Parallel with this flight-test program, a force-test investigation was undertaken with the objective of developing simpler propeller-wing-flap configurations that could deflect the propeller slipstream and also could be retracted into a conventional monoplane wing configuration.

The results of these two programs, along with a more recent study of the characteristics of propellers suitable for VTO application, will be reviewed in this paper. It will conclude with an illustration of a possible VTO transport configuration and will show an estimate of the performance of this configuration.

Slipstream-Deflection Studies

There are obviously too many possible configurations that may be used to deflect the propeller slipstream to permit a detailed systematic investigation of all variables. Instead, the approach has been to test a few general configurations to indicate the general possibilities, with the assumption that detailed development of the more promising arrangements could come later, possibly in connection with specific airplane projects. Some of the configurations that have been investigated

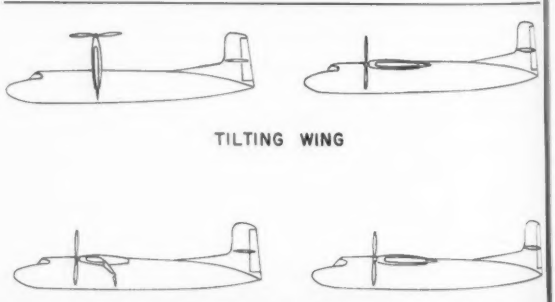

Fig. 1. Two types of VTO airplanes.

Presented at the VTOL Aircraft Session, Twenty-Fourth Annual Meeting, IAS, New York, January 23–26, 1956.

* Aeronautical Research Scientist.

are shown in Fig. 2. The tilting-wing configuration (upper left), of course, provides a basis of comparison; the data have been reported in references 2 and 3. The data on the plain flap configuration with vanes have been reported in references 1, 4, and 5. The characteristics of the other configurations will be reviewed in subsequent figures. A convenient method of presenting the results of slipstream-deflection tests is illustrated in Fig. 3, along with some results for a slotted-flap configuration. It should be remembered that we are discussing tests at zero forward speed so that the only forces present are those due to the direct propeller thrust and the effect of the propeller slipstream on the wing. The propeller thrust is shown by the horizontal vector. With the flaps deflected, a lift and a drag force will be produced by the slipstream. The drag, of course, subtracts from the thrust, and, by plotting the difference $(T - D)$ against the lift, we obtain the end point of a resultant-force vector which gives us an indication of the effective turning angle and the amount of thrust lost in the turning process. For the vector shown, 55° turning was obtained with a loss of about 5 per cent of the thrust.

It is, of course, not necessary to obtain a full 90° turning if we can allow the airplane to assume some nose-up angle for take-off. Probably 70° turning—that is, a 20° ground attitude—would be satisfactory for most cases.

The data obtained with one slotted-flap configuration[6] are also shown in Fig. 3. The lines shown represent the faired curve through points obtained with various flap deflectors. With the rear flap only, a turning angle of about 30° can be obtained. By using a combination of two slotted flaps, the turning angle is increased but at the expense of a gradual loss in resultant force. With this configuration, we can reach about 70° turning with a loss of 10 per cent of the thrust. These results were obtained with 30 and 60 per cent chord slotted flaps on a wing that had a basic chord of about three-fourths of the propeller diameter. Obviously, we would expect the turning angle to be a function of the size of the wing with respect to the size of the propeller. In searching for a size factor to correlate with the turning angle, the ratio of flap chord to propeller diameter was found to give some correlation, as illustrated in Fig. 4.

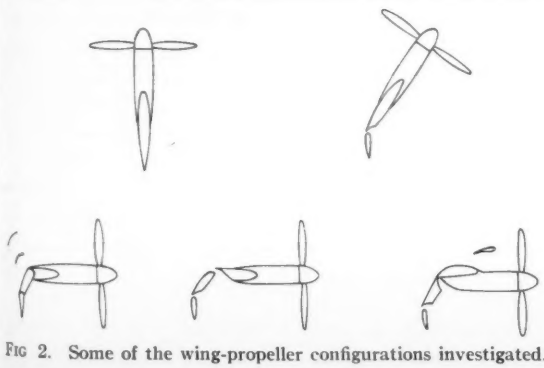

FIG 2. Some of the wing-propeller configurations investigated.

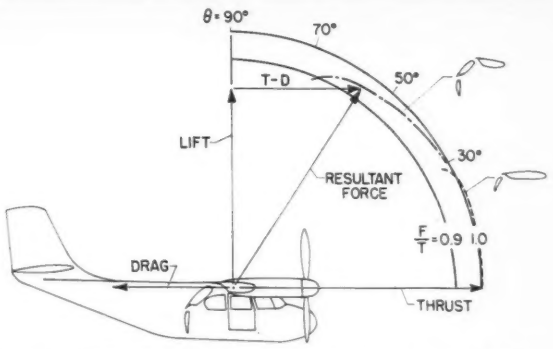

FIG. 3. Slipstream deflection by the slotted-flap configuration.

Here we have plotted the turning angle obtained as a function of the extended flap-chord to propeller-diameter ratio for single and double slotted flaps. In the case of the double flap, the extended flap chord is defined as the sum of the chords of the two elements. The importance of flap chord in turning the slipstream is obvious, as is the importance of using two flap segments rather than one. These results are for configurations with a symmetrical airfoil, without incidence and without auxiliary vanes. These modifications can be used to increase the turning somewhat, particularly at the lower turning angles.

Now that we have an idea of what it takes to turn the slipstream (out of ground effect, at least), there are two problem areas that must be considered. The first of these concerns the diving moments associated with the large flaps used as shown in Fig. 5. Here we have the pitching-moment parameter M/TD plotted as a function of turning angle for a number of configurations. The pitching-moment parameter used (pitching moment divided by thrust times diameter) is nondimensional and represents an effective displacement of the thrust axis from the center of gravity—that is, a value of $M/TD = -0.20$ indicates that the thrust axis would have to be lowered 20 per cent of the diameter to trim the configuration. The data shown here are referred to a center of gravity at 45 per cent chord, 12 per cent chord below the wing chord plane. With the thrust axis on

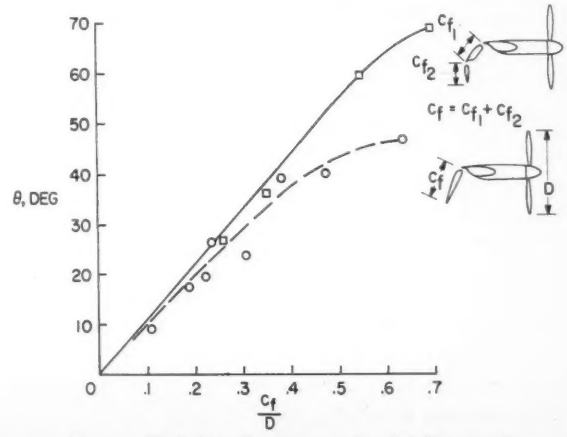

FIG. 4. Variation of turning angle with flap chord.

the chord plane, the slotted-flap configuration exhibits appreciable diving moments. Lowering the thrust line 10 per cent of the diameter reduced the pitching-moment parameter by 0.1, as would have been expected. Lowering the thrust axis further will reduce the moments even more; however, at 20 to 25 per cent diameter the turning begins to suffer.

Another possible way to reduce the diving moments may be to use a large-chord leading-edge slat,[7] as shown in the two upper sketches. With the slotted-flap wing, combining the slat with the lowered thrust axis almost trims the moments for the configuration shown. The slat is used in a much higher and more forward position than is normally thought of for a slat and is set at a relatively high angle of attack. The moment contribution of the slat, of course, changes with slat angle of attack, and this suggests that the slat may be used as a longitudinal-control device.

The top sketch represents a somewhat different flap configuration. To give it a name, the forward segment is being referred to as a sliding flap.[8] Some of the reasoning used in arriving at this configuration may be of interest. The pitching moment can be considered as arising from the fact that the resultant force is effectively at the center of the deflected slipstream as it leaves the wing. A flap system that moves aft as the flaps are extended would tend to increase the diving moments. With the slotted-flap system that was used here, the lip of the first slot was at 57 per cent chord; the flap system did most of the job of turning the slipstream aft of this point, which might be referred to as the point of first turning. It follows, then, that the pitching moments can be reduced if the flap system and the point of first turning of the slipstream can be moved forward. This at first appears to be in conflict with the requirement to keep a reasonable amount of the wing "fixed" for structural purposes. The sliding flap was evolved as a possible means of meeting both requirements. Approximately 50 per cent of the chord is fixed for structural purposes. The flap is pivoted on the lower surface at the 35 per cent chord point and arranged to slide up the back of the fixed part on an arc with a radius of 15 per cent of the chord. In the retracted position, the lip of the flap extends forward to the 35 per cent chord point. The point of initial turning has been moved forward then to the 35 per cent chord point, and, as a result, nose-up moments rather than diving moments are exhibited for the center-of-gravity positions shown.

There appear, then, to be a number of ways to keep the pitching-moment characteristics of a slipstream-deflection configuration within reason.

Two problem areas were mentioned earlier. The second of these is the effect of the ground on the turning characteristics. This is illustrated briefly in Fig. 6. With the slotted-flap configuration and the thrust axis on the chord plane, a turning angle of about 65° and a ratio of resultant force to thrust of 92 per cent are obtained out of ground effect. However, as the ground is approached, the data indicated by the dashed line indicate first an additional loss in resultant force, then a large loss in turning angle, and finally a small gain in resultant force. A loss of about 20° of turning is indicated.[9]

Tuft studies of the flow around the wing indicated that near the ground much more of the slipstream was going over the wing than went over the wing out of ground effect. Lowering the thrust axis and installing a leading-edge slat (center sketch) effectively controlled this flow and greatly improved the characteristics within ground effect. Out of ground effect, however, the resultant force was reduced somewhat.

The configuration using the sliding flap (top sketch) is the most promising configuration tested to date. A turning angle of about 70° has been obtained, with a loss of only 1 or 2 per cent of the thrust near the ground. Also, this configuration was shown in Fig. 5 to have the most favorable pitching-moment characteristics. Out of ground effect, however, this configuration achieves a resultant force to thrust ratio of only about 0.85.

The discussion up to this point has dealt with the characteristics of wing-flap-propeller combinations at zero forward speed. It has been shown that the angle through which the slipstream can be turned is a function of flap-chord to propeller-diameter ratio and that turning angles of the order of 70° can be achieved. The diving moments and the effects of the ground can be controlled effectively by lowering the thrust axis, adding a large leading-edge slat, and choosing the proper flap configuration. We can turn now to the problems of propellers for VTO airplanes.

Propeller Characteristics

There are conflicting requirements in the design of propellers for VTO airplanes. Vertical take-off requires high static thrust capability or a high ratio of static thrust to available horsepower. High static thrust capability tends to compromise the cruise efficiency.

Propeller disc loadings have increased continually during recent years, especially since the advent of the turboprop engine. These increased disc loadings have caused appreciable losses in static thrust. In the period prior to World War II, static thrust capabilities of 3 lbs. per hp. were common. This gradually fell to about $2^1/_2$ lbs. per hp., which figure is presently used for approximate calculation of thrust from available power in present-day transport-type airplanes. As disc loadings continue to increase, this figure has approached 2, and, in fact, on one particular turboprop installation in which the propeller is of the supersonic type, this value has dropped to 1.8 lbs. per hp.

This, of course, is in the wrong direction as far as VTO aircraft are involved. The factors that are important in producing a high static thrust can be reviewed by an examination of the expression for static thrust

$$T = (550\,\eta\,hp\,D\sqrt{\pi\rho/2})^{2/3}$$

where

T = thrust, lbs.
D = propeller diameter, ft.
hp = brake horsepower of the engine
η = static thrust efficiency or figure of merit as used in helicopter work

For a given horsepower then, the only way to increase the static thrust is to increase the diameter and the efficiency. At present, a diameter of about 20 ft. appears to be a state-of-the-art limit for conventional propellers. The efficiency can be maximized by use of a lot of camber—that is, high design lift coefficient. Also, wide chord blades and as high a tip speed as possible without encountering compressibility losses help to increase the static thrust capability of the propeller.

A propeller designed for maximum static thrust capability is shown in Fig. 7. This figure shows the developed blade plan form for the propeller and the blade-form curves. The propeller has a diameter of 20 ft., a blade chord of 18 in., and a thickness ratio variation from 4 to 10 per cent. It has 0.5 design lift coefficient, uniformly applied, and has a twist distribution for operation at a forward Mach Number of 0.7. The summary characteristics of the propeller are shown in Fig. 8.

This propeller, when analyzed on the basis of standard methods for calculating static thrust, has a static thrust efficiency of 0.78 and, if used with the T-56 turboprop engine, would provide a static thrust of 15,100 lbs. or a disc loading of 4.3 lbs. per hp. Of course, for static operation, the inboard sections are mostly stalled due to the applied pitch distribution so that the outer portion of the blades is carrying most of the load; however, this is probably satisfactory in that only low section dynamic pressures are available in the inboard regions. The manner of pitch distribution application is a subject for further study, and it is possible that, for this particular propeller, higher static thrust could be provided with a slightly revised pitch distribution. The propeller has a cruise efficiency of 78 per cent at a forward Mach Number of 0.7.

The weight of the propeller is 950 lbs., using conventional components. The stresses would be quite low due to the low rotational speed of 900 r.p.m., and solid dural construction could be used.

A propeller design for maximum cruise capability with this engine is not shown but would, in general, correspond to conventional modern propeller practice. The diameter would be about 14 ft., and the plan form would look much like those of propellers in use today on modern transport airplanes, though somewhat thinner. The cruise efficiency would be about 89 to 90 per cent;[10] however, the static thrust would be in the neighborhood of only 8,800 lbs. If we try to design a VTO airplane using these propellers, we find that we have an airplane without pay load or range, whereas it will be shown later in the paper that the use of the propeller designed for maximum static thrust will allow us to design an airplane with acceptable range and pay load.

It appears that there is need for further study on details of VTO propeller design that would encompass possible devices that would provide high thrust such as boundary-layer control, flaps, and possibly shrouds. At the present time, however, using conventional design procedures maximizing static thrust, propellers can be designed with sufficient static thrust capability for VTO transport airplanes.

Stability and Control

Flight tests have been made with the flying models shown in Figs. 9 and 10 to study the stability and control characteristics of both the tilting-wing and deflected slipstream configurations.[3, 4, 11] For the tilting-wing model shown in Fig. 9, the wing and propellers rotate to 90° incidence to provide lift for hovering flight. With the deflected slipstream model shown in Fig. 10, the slipstream of the conventionally mounted propellers is deflected downward about 70° by a 65 per cent chord plain flap and a cascade of auxiliary turning vanes above the wing. To perform the transition to normal forward flight, the flap is rotated upward and the turning vanes are retracted into a slot in the wing. The controls of the two models are the same. For control in hovering flight, the left and right halves of the wing trailing-edge flap are moved back and forth together to provide pitch control and differentially to provide yaw control. The pitch of the outboard propellers is varied differentially to provide roll control. In normal forward flight, the wing trailing-edge flaps are used as ailerons for roll control and the elevators and rudder are used for pitch and yaw control.

The flight test[3, 4] showed that vertical take-offs and landings could be performed satisfactorily. Because of the ground effect discussed previously, the attitude of the model near the ground was about 5° higher than in hovering out of ground effect. The main problem encountered in take-offs and landings (and in hovering flight close to the ground) was that the presence of the ground caused an upwash at the horizontal tail which caused a strong nose-down moment when the model was on or near the ground. The adverse effect of this upwash could be eliminated by the use of negative tail incidence to align the tail with the direction of the flow which was upward at an angle of about 20° to the horizontal. The angle of this upwash was a function of the distance behind the wing and above the ground so that the amount of negative incidence required would depend on the tail location.

The stability and control of the models in hovering flight were generally satisfactory, except for an extremely unstable pitching oscillation. This oscillation was more unstable for the deflected slipstream model than for the tilting-wing model. It was possible to control the models in pitch without the use of artificial stabilization, although the use of artificial damping in pitch was desirable for the deflected slipstream model.

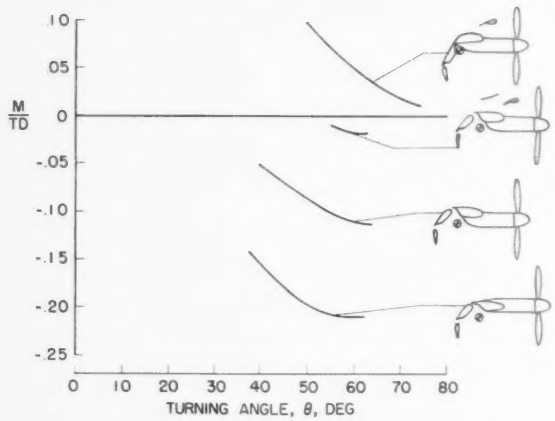

FIG. 5. Effect of configuration on pitching moments.

PROPELLER DESIGN CONDITIONS

HORSEPOWER (SEA LEVEL)	3500
FORWARD MACH NUMBER	.07
ADVANCE RATIO	2.3
ALTITUDE, FT.	35,000

PROPELLER CHARACTERISTICS AND PERFORMANCE

DIAMETER, FT.	20
BLADE WIDTH, FT.	1.5
NO. OF BLADES	3
AIRFOIL SECTIONS	16-SERIES
DESIGN LIFT COFFICIENT	.05
STATIC THRUST (SEA LEVEL), POUNDS	15,100
STATIC THRUST FIGURE OF MERIT	78 PERCENT
EFFCIENCY AT M=0.7	78 PERCENT

FIG. 8. Propeller characteristics.

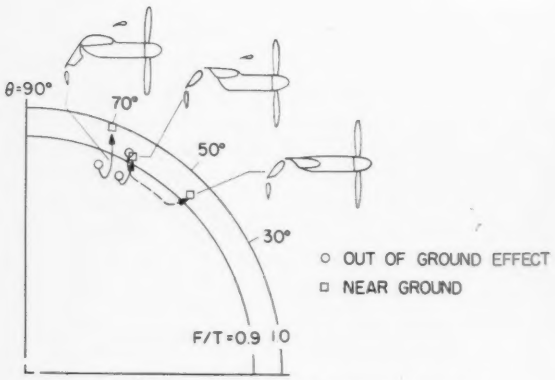

FIG. 6. Effect of ground on slipstream deflection.

FIG. 9. Tilt-wing configuration.

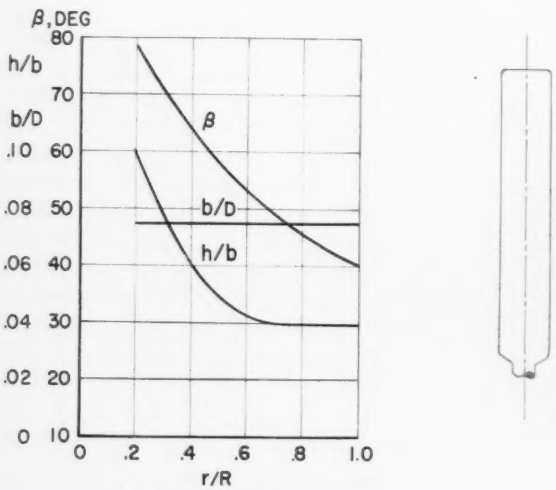

FIG. 7. Propeller blade form curves.

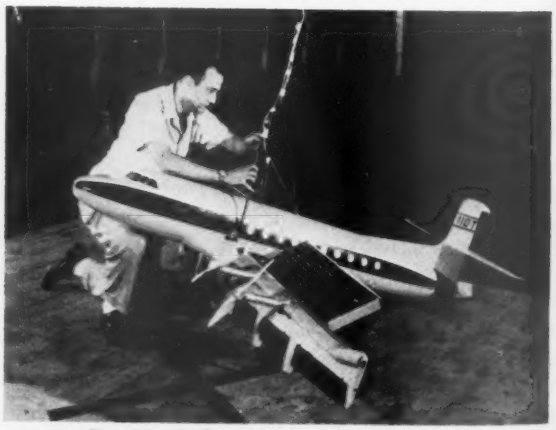

FIG. 10. Deflected slipstream configuration.

It was possible, in fact, to make the pitching oscillation of either model completely stable by the use of a pitch damper which consisted of a rate gyroscope that sensed the pitching velocity and caused the wing trailing-edge flap to deflect to oppose the pitching velocity.

To date, only the tilting-wing model has been flown in the transition range between hovering and normal forward flight.[11] It has been possible to make the transition successfully, in fact easily, for some conditions. The transition flight tests were made by flying the model in the Langley full-scale tunnel where the rate at which the air speed can be increased or decreased is relatively slow. The tests therefore demonstrated that the model could be flown for protracted periods of time at any speed in the transition range.

Three problems were encountered in the transition tests. The most obvious was that the roll and yaw controls changed function as the model performed the transition. Differential deflection of the wing flaps, which provided yaw control in hovering, provided roll control in forward flight; and differential changes in pitch of the outboard propellers, which provided roll control in hovering, caused mainly yawing moments in normal forward flight. It was not necessary to use a complicated proportional control-mixing device to handle this change in the function of the controls. At a speed of about 15 m.p.h., the wing flaps were cut out of the yaw control system and only the rudder was used for yaw control. At a speed of about 30 m.p.h., the wing flaps were connected into the roll control system to serve as ailerons. It might be desirable to cut the propeller pitch control out of the roll control circuit at high speeds, but this point was not brought out by the model tests since they were not carried to a sufficiently low angle of attack. They were carried below the power-off stall angle, however.

Another problem encountered in the transition tests was that, with the fuselage approximately horizontal and the wing at about 25° angle of attack, the model had a relatively lightly damped Dutch-roll oscillation, as might have been expected because of the effect of the wing incidence in keeping low the inclination of the principal longitudinal axis of inertia.[12] The Dutch-roll oscillation is especially excited by the use of a roll control which gives a favorable yawing moment. For this reason, use of the wing flaps, as well as the propeller pitch, for roll control was beneficial.

The most serious problem encountered in the transition tests was a nose-up moment caused by the propellers at low speeds where the elevator was not very effective. Because of this nose-up moment, the model could not exceed a certain extremely low forward speed (corresponding to about 70° angle of attack of the wing) except with forward locations of the center of gravity and wing pivot. Since the center-of-gravity range is also limited by the pitching moment available for trim in hovering, the allowable center-of-gravity range of the model was small. A design feature which might greatly reduce the problem of the nose-up moments at low forward speed is a configuration in which the center of gravity of the wing-nacelle-propeller combination is well ahead of the wing pivot. In this case, the center of gravity of the airplane would move forward as the wing incidence was reduced, instead of moving rearward as was the case for the flying model.

The results of these tests suggest the need for a more powerful pitch control, perhaps a jet-reaction control at the rear of the airplane, for the hovering and low forward speed conditions. The use of some other device than the wing flap for pitch control in hovering flight would be necessary in any event for a high wing configuration since the wing flap would not have any appreciable moment arm for producing the large pitching moments required for adequate control.

Hypothetical VTO Airplane

The preceding sections of the paper have indicated that VTO transport airplanes are feasible from various individual considerations. In order to show how the features required from various considerations can be fitted into the design of a practicable transport airplane, the layout of the hypothetical airplane shown in Fig. 11 was made and the performance was calculated. This layout is not intended to represent an optimum design or even a design for the mission in which a VTO transport would find its greatest usefulness. The extensive studies required to select an optimum design and optimum mission were far beyond the scope of this paper.

The layout was based on the use of the T56 turboprop engine and the 20-ft.-diameter propeller described in the section on propellers. These produce a total static thrust, including engine jet thrust, of 63,000 lbs. The propellers are interconnected with gears and shafts so as to maintain as much thrust as possible and keep the thrust symmetrical in the event of failure of one or more engines. The design incorporates a combination of wing tilt and slipstream deflection. The reasons for this choice will be brought out later. At a design gross weight of 60,000 lbs., the useful load was estimated at 19,000 lbs.—10,000 lbs. of cargo or 45 passengers, 500 lbs. for crew, and 8,500 lbs. of fuel. With this fuel, the maximum still-air range at a speed of 400 knots (0.70 Mach Number) and an altitude of 40,000 ft. would be about 1,300 nautical miles. Allow-

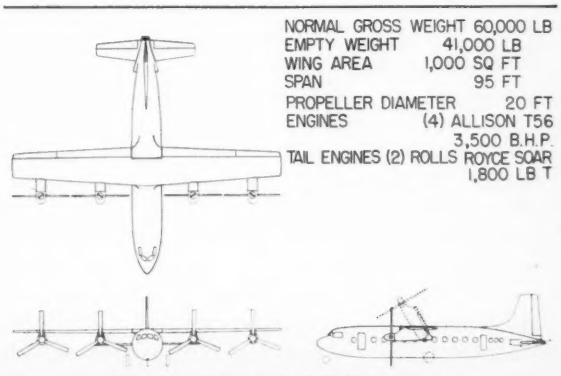
NORMAL GROSS WEIGHT 60,000 LB
EMPTY WEIGHT 41,000 LB
WING AREA 1,000 SQ FT
SPAN 95 FT
PROPELLER DIAMETER 20 FT
ENGINES (4) ALLISON T56 3,500 B.H.P.
TAIL ENGINES (2) ROLLS ROYCE SOAR 1,800 LB T

Fig. 11. Hypothetical VTO transport.

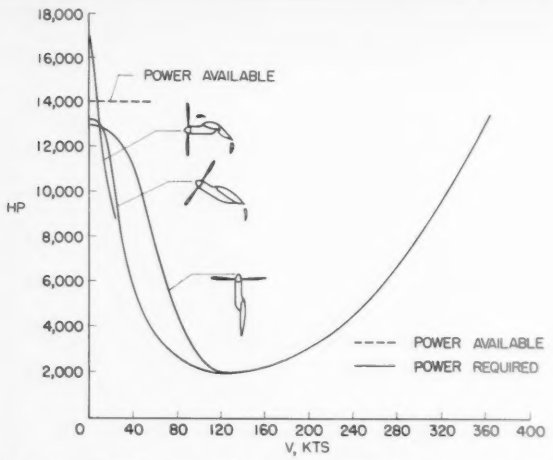

FIG. 12. Horsepower required out of ground effect; sea-level standard.

ing for climb, let-down, and fuel reserve, this should give a normal operating range of about 1,000 nautical miles.

Pitch and yaw control in hovering and at low forward speeds are provided by two small turbojet engines, such as the Rolls-Royce Soar, at the rear of the fuselage with vanes to deflect the jet exhaust. Roll control in hovering is provided by varying the pitch of the two outboard propellers differentially. Conventional ailerons, elevator, and rudder are provided for control in normal forward flight, during which time the controls for hovering flight would not be operating.

The wing configuration shown was chosen on the basis of the power-required curves shown in Fig. 12. These curves were calculated for the design gross weight of 60,000 lbs. at standard sea-level conditions. The tilting-wing arrangement is seen to require the least power for vertical take-off, but at low forward speeds the power required is much greater than for the other two. The deflected slipstream configuration (top sketch) requires about 4,000 hp. more than the tilting-wing configuration at zero forward speed because of the thrust lost in deflecting the slipstream. The power required drops off rapidly with forward speed, however, and above about 10 knots this configuration requires much less power than the tilting-wing configuration. Also, these data apply out of ground effect. Within ground effect, the power required at zero forward speed for the deflected-slipstream configuration would be only slightly greater than for the tilting-wing configuration. If we were considering the design of an STOL airplane, a heavily flapped wing such as this would probably be the choice.

The combination of wing tilt and slipstream deflection (center sketch) appears to be a good compromise and was chosen for the example airplane because its power requirements are relatively low throughout the speed range. The choice of this configuration for the example airplane should not, however, be construed as a blanket recommendation. Other considerations such as relative weight, complexity, cost, and maintenance problems may alter the decision in many instances.

With the wing configuration chosen, the power available exceeds the power required by about 800 hp. This, combined with the engine jet thrust, provides a thrust margin of 5 per cent for take-off and landing at standard sea-level conditions.

At altitudes up to 6,000 ft. and ambient temperatures up to 100°F., water and alcohol injection could be used to maintain the power required for vertical take-off and landing. Without liquid injection, the vertical take-off weight would have to be reduced to 45,000 lbs. and useful load would be only 4,000 lbs.

The airplane could, of course, be operated under high temperatures and altitude conditions without liquid injection by allowing it to have some take-off and landing run. The power-required curve for the extreme conditions of an altitude of 6,000 ft. and 100°F. is shown in Fig. 13. Without liquid injection, the total power available would be a little over 10,000 hp., and the minimum speed of the airplane would be about 30 knots. The speed for minimum take-off distance over a 50-ft. obstacle would be somewhat higher, however, and would correspond to point A or about 40 knots. Similarly, the speed for minimum landing distance over the same obstacle would be at point B or about 48 knots. There is serious doubt, however, about the feasibility of operating far up on the back part of the power-required curve. Because of the steepness of the curve, sudden wind shifts would require large changes in power settings. We may possibly even run out of available power. For this reason, it may be found necessary to operate farther down on the curve, such as at point C.

The consequence of this on the landing and take-off distances is shown in Fig. 14. The minimum take-off distance is about 400 ft. and is obtained at 40 knots. If we must operate at point C, however, the take-off distance is increased to 1,100 ft. The minimum landing distance is 800 ft. at 48 knots, and operating at point C would increase this to 1,250 ft. In this case, operating at the higher speed is not too severe because, for this wing configuration, even the minimum landing distance is rather long.

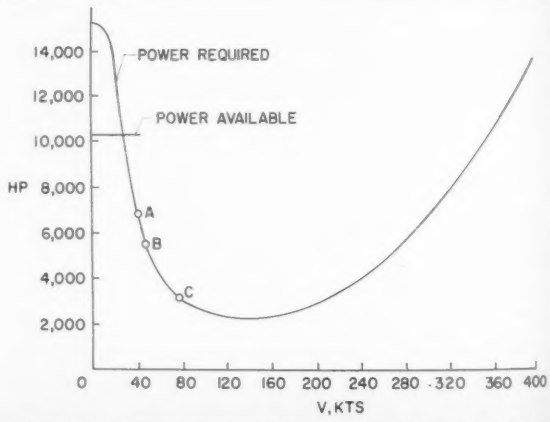

FIG. 13. Horsepower required at 6,000 ft. altitude, 100°F.

Note that the minimum landing distance is twice the minimum take-off distance. This serves to illustrate that the landing problem is probably the critical one for STOL or overloaded VTO airplanes. The reason is indicated in the flat approach shown for this landing speed. As the speed is reduced, the airplane depends more and more on the propeller slipstream for lift. To get the slipstream, we need thrust which counteracts the drag and results in a flat approach. If the angle of attack is increased to overcome this effect, the wing stalls. Control of this wing stall at high powers, low speeds, and high angles of attack (perhaps by use of slats or boundary-layer control) may be necessary in order to obtain short landing distances.

These calculations, of course, assume constant velocity in the approach and flair. It would be possible to make a level approach to the obstacle at some low speed and then reduce power. The airplane would drop and pick up speed, the descent would have to be arrested with power, but the landing distance would probably be shorter than those shown. We are, however, again confronted with the problem of how far up the back part of the power-required curve we can operate.

These problems (operating on the back of the power-required curves and flat landing approaches) are two of those associated with STOL or overloaded VTO airplanes which need considerably more study, and it may be that they will have to await actual flight-test experience with flying mock-ups of these aircraft in order to arrive at the final answers.

How the performance and operating costs of the example vertical take-off transport design compare with those of conventional airplanes and how much the vertical take-off and landing feature is worth to various types of operators are questions beyond the scope of the present paper. A brief check, however, has indicated that a conventional airplane designed for the same load, speed, and range as the example vertical take-off transport would weigh only about 75 per cent as much and require only half as much power. No attempt has been made to determine whether or not, or under what circumstances, the vertical take-off features are worth the greater initial cost and greater operating costs. The main point that can be made at present is that vertical take-off transport airplanes with a useful degree of performance can be designed and built at the present state of the art.

Conclusions

This paper has summarized some of the recent NACA work on vertical take-off transport airplanes.

It has been shown that the principle of redirecting the slipstream can be used and that slipstream angles of the order of 70° can be obtained. Also, the diving moments and the effects of the ground on these configurations can be controlled by proper choice of configuration.

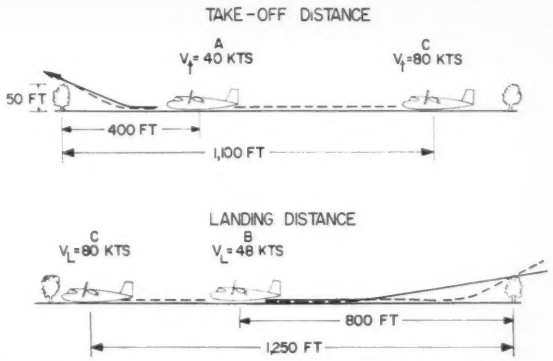

FIG. 14. Take-off and landing distance, 6,000 ft. altitude, 100°F.

The factors involved in the design of propellers to provide high static thrust have been reviewed, and it has been pointed out that large diameter, considerable blade camber, and blade width are required to obtain high static thrust.

The stability and control characteristics of these airplanes have been examined, and it has been shown that airplanes of this type can be flown without artificial stabilization. Various forms of instability may exist in some conditions, however, and may make the use of some degree of automatic stabilization desirable.

The design of an example airplane indicates that VTO transport airplanes with a useful degree of performance can be designed and built at the present state of the art.

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(*Continued on page 84*)

A quality control program that affords detection of defective materials and verification of materials properties by the use of radiography, ultrasonics, and the spectrometer, metals comparator, magnatest, and magnegage.

W. J. Maloney, Jr.†
Fairchild Aircraft Division

The Application of Nondestructive Testing by a Manufacturer of Military Aircraft*

Introduction

Without nondestructive testing, no modern-day production can be accomplished. This is inherent in the word "nondestructive." It is immediately apparent that if you destroy everything you make, you produce nothing, and you either fail financially or become purely a research organization. It is also true that to do no inspection at all is to be nondestructive, but everyone will agree that quality control in aircraft manufacturing is necessary. Fairchild Aircraft Division builds cargo aircraft for the military services, and, because we have delivered over 1,200 of these aircraft made up of an average of 22,000 separate parts (excluding radio, engines, propellers, and fasteners such as rivets, bolts, etc.), we must be using nondestructive test methods and equipment.

In most air-frame companies, inspectors are considered nonproductive employees or overhead because they do not physically produce anything. Even quality must be built in—it cannot be inspected into a product. Since it is an overhead cost, every effort must be made to balance maximum quality control with minimum costs. This is done by the use of many types of inspection "tools," some of which are statistical sampling, vendors' ratings, production-type inspection gages, and nondestructive test methods and equipment. While these tools are available, the decision as to when to use them and to what degree, or when not to use them, is the really important item in any application of quality control. For example, no air-frame contractor would radiograph every part in an airplane, nor would he totally disregard the radiographic process and not use it at all.

Typical Military Requirements

In many cases, military procurement and commercial procurement differ. It is often said that military air-frame manufacturers build and inspect to Government specifications, whereas commercial air-frame manufacturers build and inspect to meet competition. While this may be true in theory, in practice we find that few companies today produce only commercial aircraft to commercial standards; in keeping with the single-quality theory, only one quality control level is established, and therefore military specifications dictate our requirements.

Fig. 1.

These Government specifications contain such requirements as:

(1) ARCDM80-1, Homogeneity—"the physical and chemical properties must be consistent."

(2) MIL-H-6857—"The routine operation of the equipment and heat-treating procedure shall be judged by the physical properties obtained . . ." and ". . . shall be applied in a manner that will produce the utmost uniformity."

(3) MIL-H-6875A—"Unless otherwise specified by the prime contractor and the procuring activity, the mechanical properties indicated on drawings, detail metal specifications, or other applicable specifications shall be met in all cases."

"The equipment, methods, and processes used by the contractor shall be subject to the approval of the au-

* Presented as part of the Nondestructive Testing Program, National Metals Congress meeting, Philadelphia, Oct. 18, 1955.

† Assistant Chief Inspector.

thorized Government representative at the facility and the prime contractor."

(4) QA-A-277 (7075 Al. Alloy Bars, Rods, and Extruded Shapes)—"The bars, rods, and shapes shall be uniform in quality and condition, clean, sound, smooth, and free from hard spots, pipes, laps, cracks, kinks, seams, damaged ends, and other injurious defects within limits consistent with best commercial practice."

"Each bar, rod, and shape shall be carefully examined to determine conformance with the specification with respect to workmanship."

(5) QQ-A-367, Aluminum-Alloy Forgings Heat Treated—"The forgings shall be of uniform quality and condition, free from blisters, fins, seams, laps, segregations, or other injurious defects."

(6) QQ-A-601a (Aluminum-Base Alloys; Sand Castings)—"Castings shall be of uniform quality and condition, free from injurious blowholes, porosity, hard spots, shrinkage, cracks, and other injurious defects. . . ."

"Each casting shall be carefully examined to determine conformance with this specification with respect to workmanship."

A review of the above typical military requirements will show a recurring use of such terms as "free from," "uniform in properties," "injurious defects," "approval of the Government representative," and "each piece shall be." It is believed that many of these restrictive requirements are the result of a lack of knowledge of the effect of varying degrees and types of defects on the serviceability of parts. Because designers, engineers, and materials personnel do not know if a porous condition will reduce the mechanical properties by any given amount and, therefore, can be considered in the design or evaluation of parts, they make the requirements such that no defects can be present and each part must be inspected to determine that it is "free from" defects.

It is to meet these military design requirements that manufacturers constantly review basic physics principles in order to adopt them to equipment for the verification of material properties and the detection of defects or nonhomogeneous conditions. This has been done by Government agencies and—either directly or on contract—by research institutions, air-frame manufacturers, equipment manufacturers, and other allied industries. As the result of this research, many instruments and processes have evolved which have applications to most of our problems, at least in theory. The general trend is now toward automatic and semiautomatic equipment not only to produce the parts but also to inspect them, thereby eliminating or reducing the human element of error. The equipment being developed must of necessity be simple of operation, versatile, easy to maintain, and dependable. Accuracy, ability to reproduce results, and sensitivity are of prime importance, as is the availability of test results to prove these features so that each user need not expend man-hours and materials on independent development programs. At the present stage of development, we can find the defects and measure them in some relative terms, but our big problem now is the evaluation of the reduction in properties and service life caused by these defects.

In general, we classify nondestructive testing into two major fields—material defects and material properties. Both are equally important when it is realized that a part can fail just as easily because of improper mechanical properties as because of a defect. At Fairchild Aircraft we use a great array of nondestructive tools, and a discussion of these methods and a review of our applications may show some that are unique but also many that are used by most military air-frame manufacturers.

Material Defects

Material defects are simply defined as discontinuities in the material which could serve as stress risers affecting the serviceability and quality of the part. They are normally detected by one or more of the following:

Radiography

Radiographic inspection is employed for the detection of *internal* defects, especially with light-metal castings fabricated from the aluminum and magnesium alloys. Analysis of a modern cargo aircraft—such as the C-119 Packet manufactured by Fairchild and now used extensively in the Far Eastern and European theaters of operations—shows that, of a total of 1,947 castings used per airplane, 1,537 are aluminum alloy, 368 are magnesium alloy, and 69 are steel. Of the

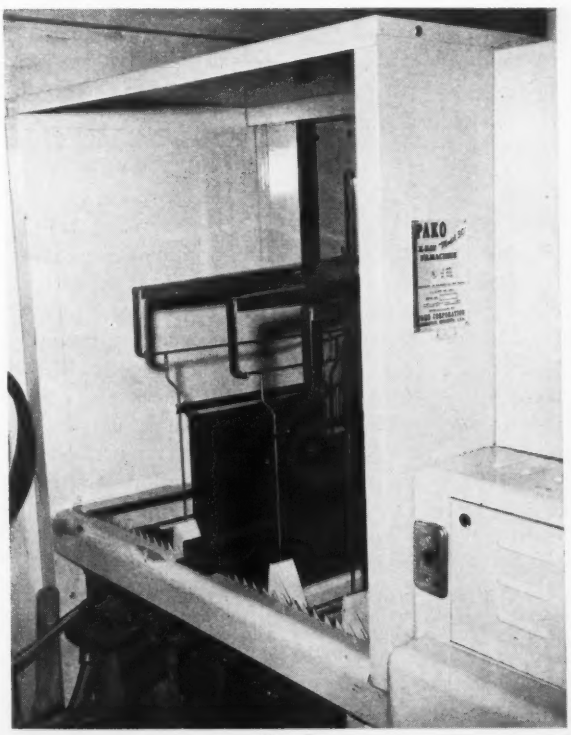

Fig. 2.

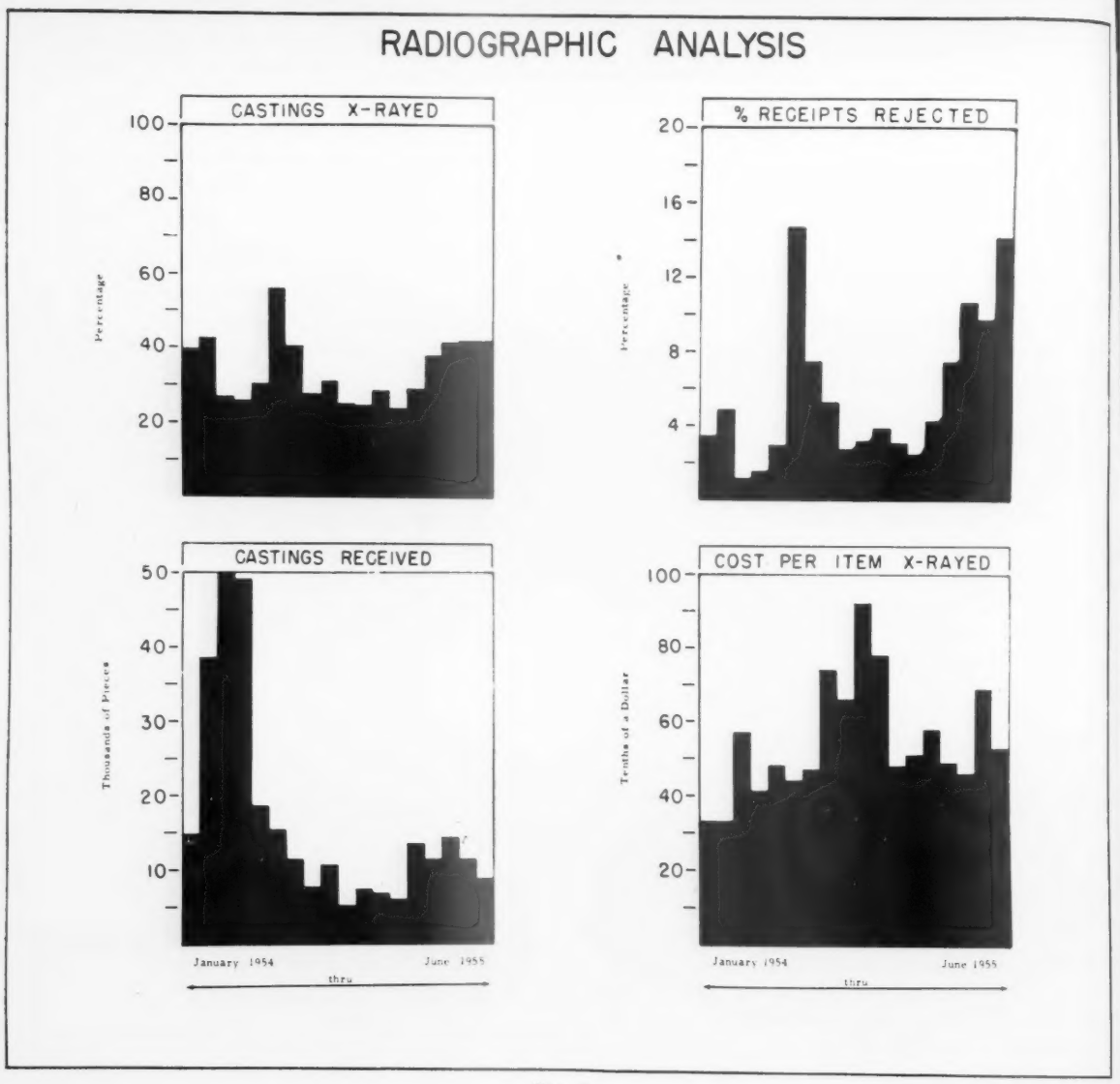

FIG. 3.

1,947 castings, 184 are actually radiographed; but, to provide overall coverage with maximum sensitivity, from one to seven different shots are made of each casting. To handle this workload, a General Electric OX-140 kv. semiautomatic radiographic unit and a Pako Filmachine Developing unit are used. Located between the receiving and the stores areas, this equipment, shown in Figs. 1 and 2, can handle one film per minute, and since installation it has been possible to:

(a) Eliminate a second shift operation of approximately 80 man-hours per week.

(b) Increase tube time by approximately 50 per cent per 8-hour shift.

(c) Reduce in-work time from receiving to stores by 20 per cent.

(d) Institute a research and development program using the old lead lined room and OX-220 kv. unit released from production operations.

As is typical of most processes used in military air-frame construction, the equipment required certifications by Air Force inspection personnel prior to use on air-frame work. During 1954, a total of 237,440 castings was received which required radiographic control, and of these, 77,884, or 32.7 per cent, were actually X-rayed. Of these, 8,549 pieces were rejected, and this rejection represents 3.60 per cent of the total receipts of castings. The radiographic material (film, developer, etc.) costs an average of 0.403 per unit X-rayed, with a labor cost of 0.149 per unit X-rayed. Fig. 3 shows a full analysis for the past 18 months.

Fluoroscopic equipment as shown in Figs. 4 and 5 is currently being evaluated.

Penetrant Inspection

Based on the theory that, normally, significant types of defects will show up in the areas of greatest stress during manufacture and service and that these areas

are the outer surfaces of the part, it becomes important to inspect these surfaces for defects. Again, normally, this would involve only an unaided visual inspection, but experience has shown that too many human errors creep in when an inspector is asked to do such a simple operation as "visual inspection." Unless complicated equipment is involved with a certain amount of mystery, the operation just does not seem important. It is often said that, if we provided our inspectors with a large black booth equipped with three 150-watt white light bulbs located behind frosted glass to hide their name and wattage and called it an "Inspectoscope" that used "ultrared sonic light waves" to reveal defects and "certified" the inspectors, we would find most defective parts. Because this is impractical, we use penetrant inspection methods to accentuate defects and aid our visual inspection.

(a) Fluorescent penetrant inspection is used almost exclusively at Fairchild in the receiving inspection area. Equipment is located near the radiographic equipment because of new military requirements (MIL-C-6021A) requiring penetrant inspection on all Class IA castings. Some few selected aluminum forgings are also FP inspected upon receipt, but our experience has shown that forgings from reputable companies do not contain surface defects in such quantity that large machining costs are lost when these defects are subsequently found after machining. Other types of penetrant inspection are, of course, used after machining. A system of individual part standards has been established which closely resembles that used for area stress marking of casting blueprints. These standards—as well as all other details, equipment, personnel, etc.—are approved by the Government representative and are under his surveillance.

(b) Dye penetrant methods are currently used only on detail parts that have been assembled and where disassembly would involve extensive rework to permit inspection by other methods and on local cold-worked areas of parts too large for other existing equipment. This is a brush or spray application that follows standard procedures. Current changes being planned in anodic processing as noted below will, however, make dye penetrant the principal surface defect method in use at Fairchild in the near future.

(c) Anodic inspection or inspection for defects after anodizing is considered by Fairchild as a penetrant method of inspection meeting all requirements of Government Specification MIL-I-6866A, and its use is authorized by MIL-I-6870 for forged aluminum-alloy parts. It is the most economical method because one process serves two purposes—namely, the corrosion protection of the part and also the basis for inspection of defects.

Laboratory tests have shown that it is equal in value to fluorescent and dye penetrant methods for *significant* defects. While the latter methods will pick up some types of indication more readily than anodic inspection, analysis shows that these are only nonrelevant types acceptable in all cases on Fairchild-designed parts. This is further proved by almost 13 years of operation wherein no part has ever failed because of a defect that should or could have been detected.

As a result of processing savings involved in the use

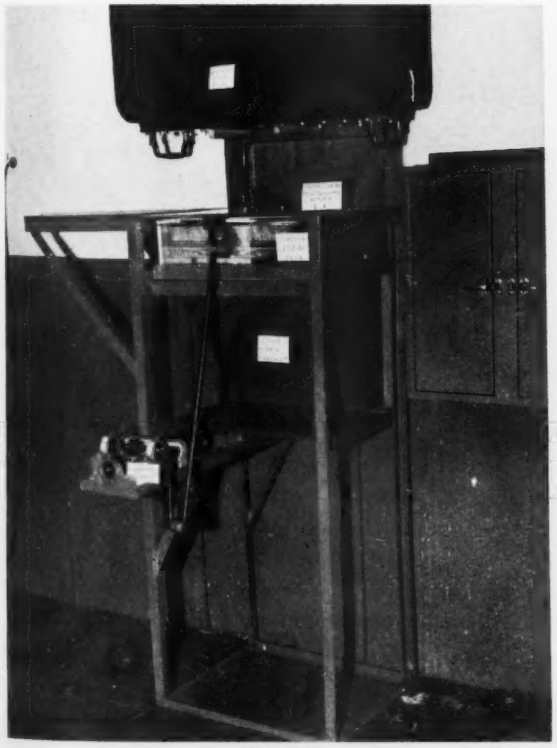

FIG. 4.

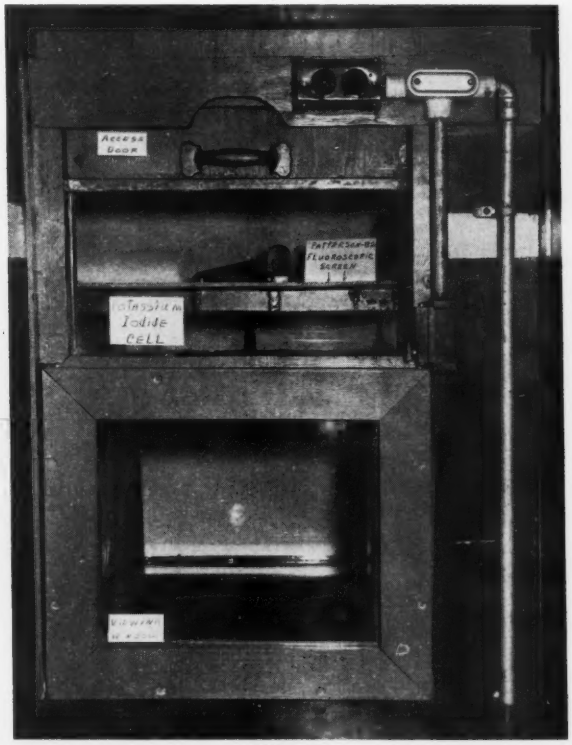

FIG. 5.

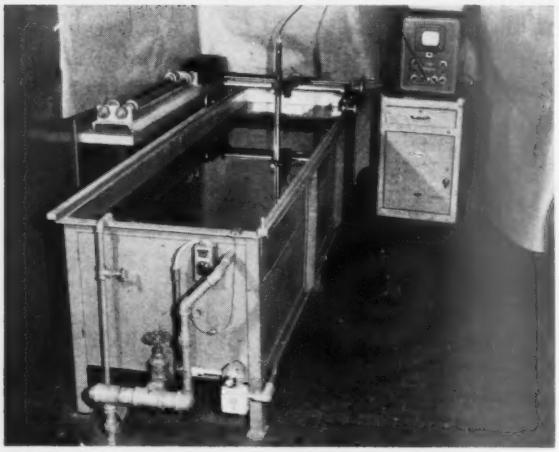

FIG. 6.

of chemical films compared to anodic treatment for corrosion protection, Fairchild is currently installing a large production setup for the use of dye penetrant inspection to replace anodic inspection. It is well known that chemical films do not provide a basis for defect detection as do anodic films. All wrought nonferrous parts, except sheet metal parts, will be inspected by this tank setup after manufacture but before processing.

Magnetic Particle Inspection

Magnetic particle inspection is to ferrous materials what penetrant inspection is to nonferrous materials, except that some discontinuities that are slightly subsurface may be resolved. This inspection process was one of the first for which military specifications were written and which required AF certification of equipment, methods, and personnel. It is also one that has caused much adverse comment in the past as to the necessity for the control, especially when the air-frame manufacturer is still responsible for the end product regardless of what degree or type of inspection medium is used and regardless of the presence of military controls or Government inspection. Much of this has now been corrected with the release of MIL-I-6870A, and Fairchild currently uses seven magnetic particle machines with which to meet the requirements of this specification. These are located in the usual places, such as receiving inspection, the heat-treat area, and detail inspection areas.

Lists of parts to be inspected for each model of aircraft are prepared by quality control laboratory personnel by surveying all blueprints for ferrous parts or assemblies, and these lists are used by Planning to route the parts to magnetic inspection on work orders. As with other modern defect detection methods, the finding of the defect is easy, but the difficult thing is to determine what to do with the defective part. Until recently, magnetic particle inspectors at Fairchild rejected for review *all* parts containing any discontinuity regardless of how small or large. Quality control laboratory personnel, previously certified as magnetic particle supervisors, reviewed each rejected part and, based on metallurgical experience and knowledge, dispositioned the final rework or acceptance of the part. Recently, we have adopted a system that will provide the inspector with detail part standards that consist of drawings marked to show defects permitted by definitive areas.

Ultrasonics

Just as many people these days wrongly interpret statistical sampling to be the main item in quality control, they also wrongly interpret the use of ultrasonics to be the main item in nondestructive testing. In reality, it is merely another tool to do but one of the jobs of quality control and has its distinct limitations and applications. Its use has brought on many problems—mainly, that of now finding conditions in materials which probably always existed in the past and which we unknowingly accepted but now, knowingly, are forced either to accept or reject. We are torn between our experience records on similar materials which do not reveal cases where these previously unfound defects have been proved to have caused failures and our theoretical knowledge (or lack thereof) as to what could happen. In this respect, the equipment development in ultrasonics has far outstripped the design evaluation of what the equipment reveals. An extensive amount of correlation is now being conducted, and practically every professional society and organization has active committees or projects on ultrasonics, including the Society for Nondestructive Testing, Aircraft Research & Testing Committee, Inspection Committee of Aircraft Industries Association, American Society for Testing Materials, Aluminum Company of America, Kaiser Metal Products, Inc., Society of Automotive Engineers, the military, etc. Much data have been published or made available on an exchange basis, but the correlation leaves much to be desired because of differences in equipment, standards, and techniques.

It is for the above reason that Fairchild is "going slow" on ultrasonics. We do have two contact scanning units used for receiving control of steel and aluminum hand-forged billets and for large extrusions, and, from what we can gather, our experience parallels that of other air-frame manufacturers. The military services are apparently also "going slow" in that they have not issued any specifications or requirements other than a general reference in MIL-I-6870A requiring approval of contractor specifications.

Submerged ultrasonic testing is being evaluated at our plant on a laboratory basis using the equipment shown in Fig. 6. This equipment is also being used for special investigations and operator training during preparation of procedures and standards.

Mechanical Impedance

No inspector is fully satisfied when he has to use separately fabricated test coupons to evaluate a part. But some processes do not lend themselves to any other type of control. One of these is structurally cementing

metal to metal where the detection of voids, low strength bonds, lack of total adhesion, etc., in the parts themselves has been extremely difficult, if not impossible, up to now. Stanford Research Institute, under contract with Wright Air Development Center, has developed and is now evaluating a mechanical impedance tester, details of which are covered by WADC Technical Report No. 54-231. This is one of the newest of the nondestructive test methods, and, while known to be used by only one air-frame manufacturer, its potential is such that all manufacturers of military aircraft may soon expect a specification requirement regarding this testing. The ARTC Western Region held a specialists meeting on this tester in early 1955 and has set up a panel for its further evaluation.

Material Properties

Material properties are defined as the design values to be met by the material, such as chemical composition; ultimate, yield, and per cent elongation; fatigue strength, etc. They are verified by one or more of the following:

Spectrometer

Fairchild Aircraft, in its production of C-119 Flying Boxcars, uses a great variety of metallic materials in many forms. Typical of these are aluminum alloys, magnesium alloys, carbon steels, corrosion-resistant steels, and copper-base alloys. These materials are further procured in sheet, plate, tubing, billet, bar and rod, cast, forged, and practically every other shape available, as well as in fabricated parts, such as bolts, nuts, bushings, stampings, etc. Because the results of processing this material into individual parts are dependent to a great extent upon the chemical composition of the material, it is essential that this be determined before the material is processed. Our experience has shown that test reports received with the material contain errors that cannot be accepted and that it is essential that all material be sampled or 100 per cent inspected upon receipt before it is color coded and stocked. This created a great volume of wet chemical laboratory analysis, and the length of time involved in analysis extended the time between receipt of materials and final stocking to a degree not acceptable with modern high production schedules.

To solve this problem without reducing the degree of receiving inspection, Fairchild laboratory personnel visited Baird Associates in 1952 and were assured that, although most Direct Readers were used for one or two materials only and were used primarily by mills and foundries, they would engineer one to cover eight or more elements in each of five materials, using simple switchover from one to the other without requiring restandardization. Fairchild received its instrument in June, 1952, and since that time has reassigned two chemists to other laboratory work while reducing the analysis time by 1,300 per cent and increasing the quantity of analysis by 300 per cent.

Raw material is received, and, dependent on the type and form, samples are cut in accordance with established procedures relative to quantity and size. This sample is forwarded to the materials laboratory where it is used for determining the metallurgical and mechanical properties, as well as the chemical composition. Since the Direct Reader does not destroy the sample, the same material is used for all tests, thereby reducing the material loss due to sampling and also ensuring more complete coordination of test results. Electronic metal comparators are subsequently used to verify the uniformity of the lot received using the sampled piece as a standard.

In addition to elimination of all overtime operations, it has been possible to complete several special investigations that would have been impractical due to the great quantity of wet analyses required and man-hours involved. Because the reduction in chemical analysis time reduced the overall laboratory report time, it was possible to revise the sampling plan to include more types and alloys and larger quantities to ensure closer aircraft material control. As an example, small forgings were previously destroyed to obtain chips for chemical analysis when mixed alloy receipts were received. Now the entire lot can be analyzed with special adapters on a Petri stand without destruction, thereby saving the cost of the forging. Analyses are made to verify that the material purchased to Government specifications actually conforms to the specifications. Because of the simplicity of operation and reliability of the instrument (shown in Fig. 7) after Baird personnel made final adjustments, it was possible to train an existing chemist in the practices and methods required in the operation and maintenance of the instrument. The

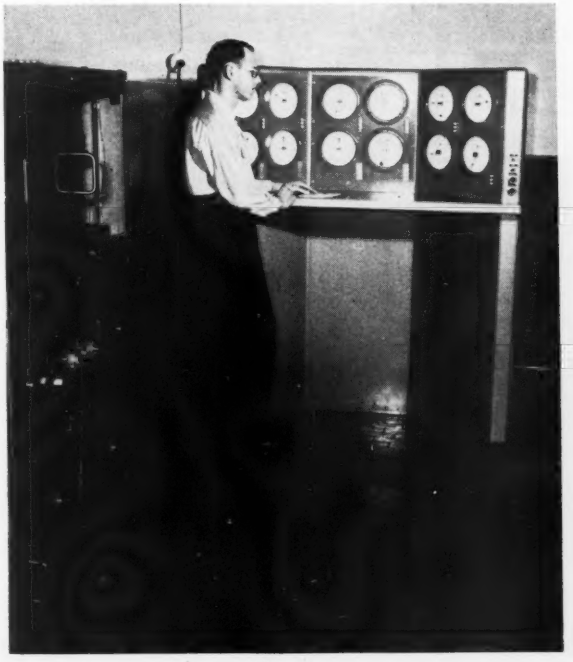

Fig. 7.

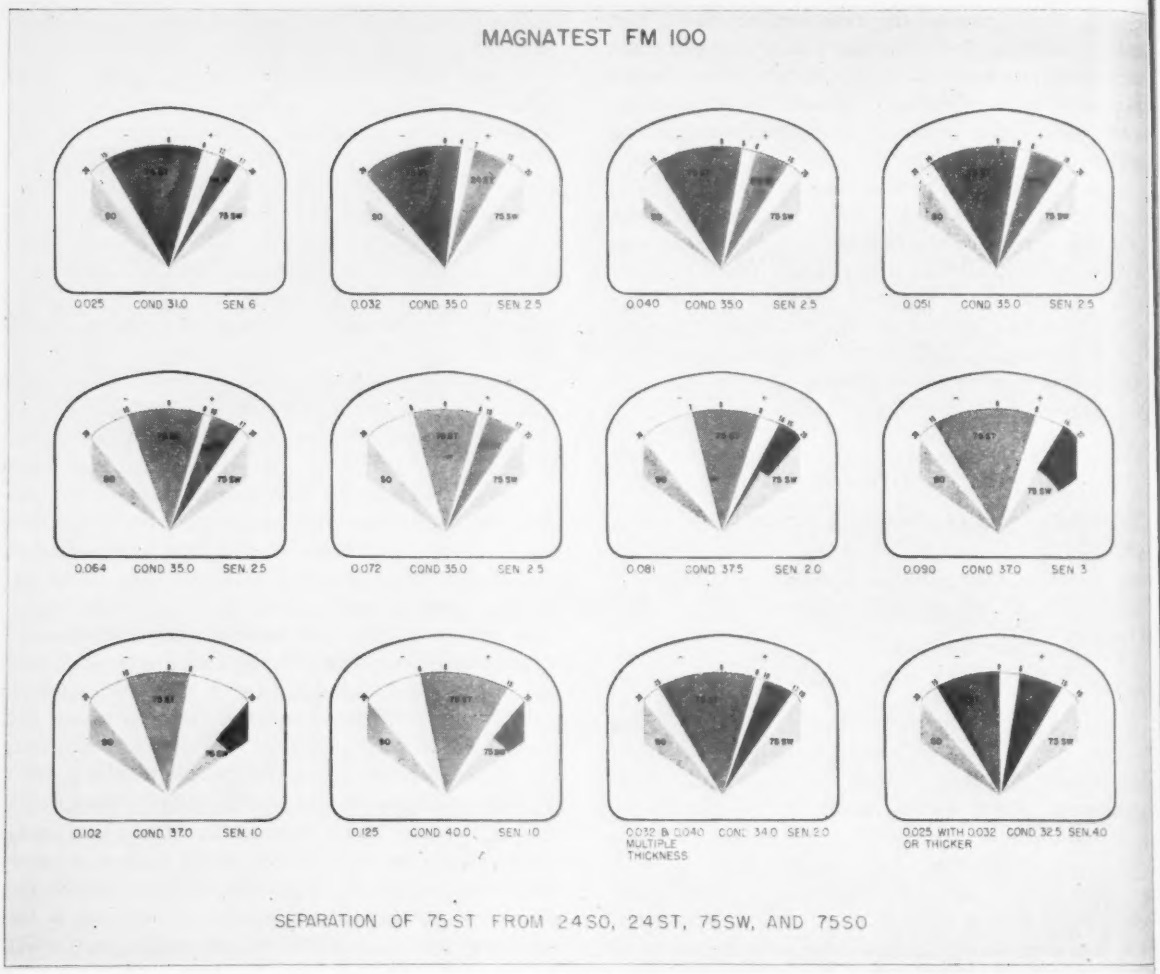
MAGNATEST FM 100
0.025 COND 31.0 SEN 6
0.032 COND 35.0 SEN 2.5
0.040 COND 35.0 SEN 2.5
0.051 COND 35.0 SEN 2.5
0.064 COND 35.0 SEN 2.5
0.072 COND 35.0 SEN 2.5
0.081 COND 37.5 SEN 2.0
0.090 COND 37.0 SEN 3
0.102 COND 37.0 SEN 10
0.125 COND 40.0 SEN 10
0.032 & 0.040 MULTIPLE THICKNESS COND 34.0 SEN 2.0
0.025 WITH 0.032 OR THICKER COND 32.5 SEN 4.0
SEPARATION OF 75ST FROM 24SO, 24ST, 75SW, AND 75SO

FIG. 8.

one remaining problem is in obtaining alloy standards to extend the range of the curves for individual elements.

Metals Comparator

Used in conjunction with the spectrometer, the General Electric metals comparator is used to provide a 100 per cent inspection for uniformity of lot on all steel bar and tubing received. Too often when tubing is ordered from warehouses, one or two lengths will be of some alien alloy, and even a tight sampling plan will miss them. Previously, it was necessary to cut a small sample from *each* bar or tube in the lot and submit it to the laboratory for chemical and hardenability tests. The amount of testing and time involved was tremendous but necessary until we conducted extensive laboratory tests on the General Electric metals comparator in 1952 which proved that the effect of military specification tolerances on alloy composition, thickness, heat-treat conditions, etc., were negligible for any one alloy. We now select one length from each lot, standardize the instrument on that piece, and compare all other lengths in the lot to the selected pieces. A sample from only the selected length is forwarded for spectrographic and metallurgical analysis. This instrument is actually one of the key nondestructive instruments in our receiving inspection giving the quality assurance required by the military services.

Magnatest

Fairchild procured a Model FM-100 magnatest in early 1953 when we were met with the problem of inspecting a complete termination storeroom of parts and assemblies in all stages of fabrication from another manufacturer. It was imperative that we determine that all 7075S parts were actually 7075S alloy and in the heat-treated and fully aged condition. Parts installed in major assemblies were our first problem, so laboratory tests were conducted on possible combinations and variations of alloys, conditions, and thicknesses using the FM-100 as a comparator. Results for two typical alloys are shown in Fig. 8. Different conductivity and sensitivity settings can subsequently be used to separate 7075ST4 and 24ST as a second operation.

Fig. 9 shows the results of laboratory tests on 2014S

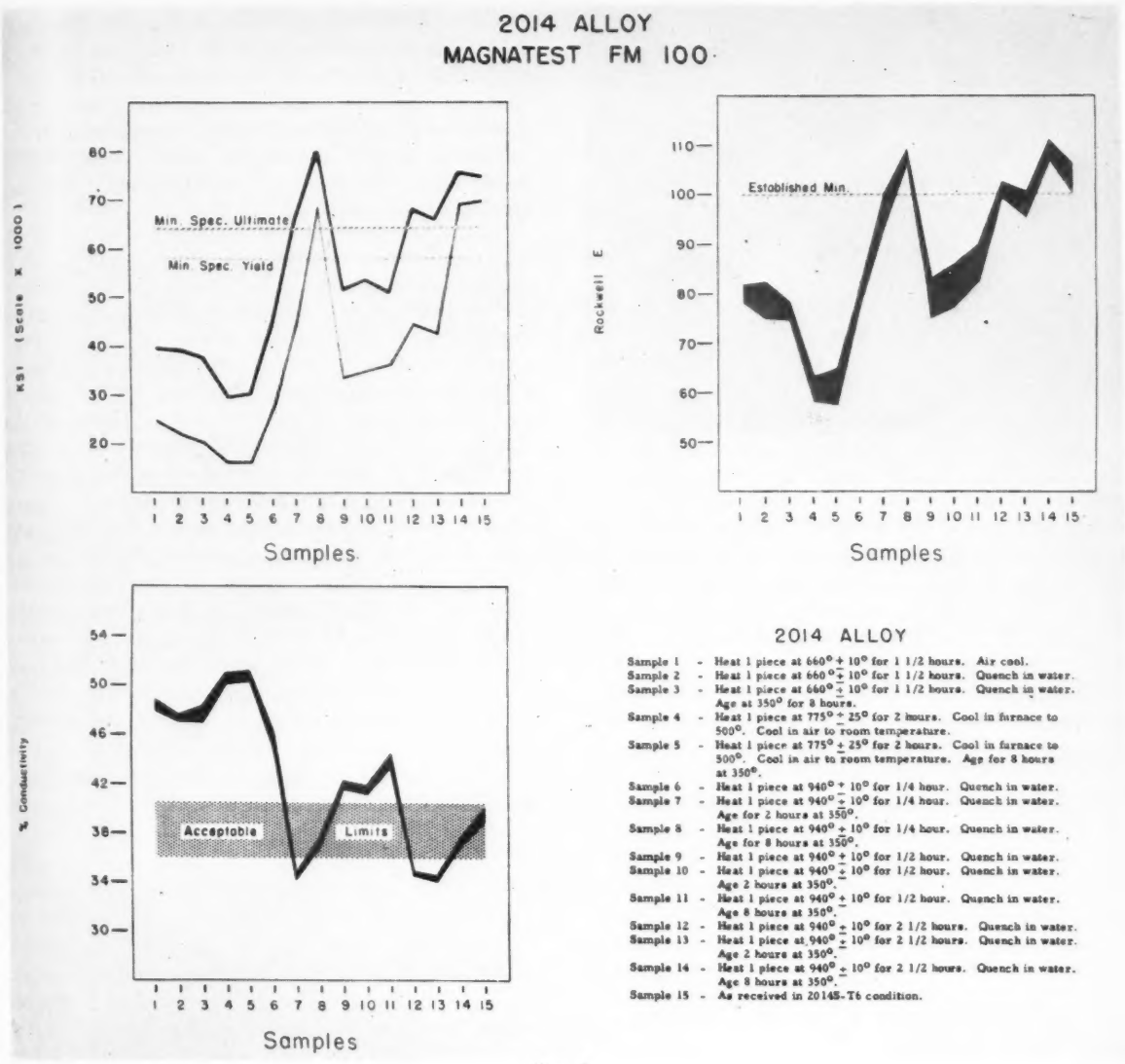
2014 ALLOY
MAGNATEST FM 100
KSI (Scale x 1000)
Min. Spec. Ultimate
Min. Spec. Yield
Samples
Rockwell E
Established Min.
Samples
% Conductivity
Acceptable Limits
Samples
2014 ALLOY
Sample 1 - Heat 1 piece at 660° ± 10° for 1 1/2 hours. Air cool.
Sample 2 - Heat 1 piece at 660° ± 10° for 1 1/2 hours. Quench in water.
Sample 3 - Heat 1 piece at 660° ± 10° for 1 1/2 hours. Quench in water. Age at 350° for 8 hours.
Sample 4 - Heat 1 piece at 775° ± 25° for 2 hours. Cool in furnace to 500°. Cool in air to room temperature.
Sample 5 - Heat 1 piece at 775° ± 25° for 2 hours. Cool in furnace to 500°. Cool in air to room temperature. Age for 8 hours at 350°.
Sample 6 - Heat 1 piece at 940° ± 10° for 1/4 hour. Quench in water.
Sample 7 - Heat 1 piece at 940° ± 10° for 1/4 hour. Quench in water. Age for 2 hours at 350°.
Sample 8 - Heat 1 piece at 940° ± 10° for 1/4 hour. Quench in water. Age for 8 hours at 350°.
Sample 9 - Heat 1 piece at 940° ± 10° for 1/2 hour. Quench in water.
Sample 10 - Heat 1 piece at 940° ± 10° for 1/2 hour. Quench in water. Age 2 hours at 350°.
Sample 11 - Heat 1 piece at 940° ± 10° for 1/2 hour. Quench in water. Age 8 hours at 350°.
Sample 12 - Heat 1 piece at 940° ± 10° for 2 1/2 hours. Quench in water.
Sample 13 - Heat 1 piece at 940° ± 10° for 2 1/2 hours. Quench in water. Age 2 hours at 350°.
Sample 14 - Heat 1 piece at 940° ± 10° for 2 1/2 hours. Quench in water. Age 8 hours at 350°.
Sample 15 - As received in 2014S-T6 condition.

FIG. 9.

alloy that was deliberately misheat-treated to produce low yield but high ultimate tensile values. Normal Rockwell tests will not detect all the defectives, whereas the magnatest unit did. This has led to such applications as detecting local "soft" spots in long extrusions and a possibility of eliminating our current heat-treat control of 7075 by the use of separate tensile coupons. The parts themselves may be tested, assuring a closer type of quality control.

Magnegage

Up to the development of magnetic-type plating gages, Fairchild and other military air-frame manufacturers were forced to run thickness tests on a measure-strip-measure basis of a sample of parts. While this destructive type of test was applicable to plating control where stripped parts could be replated, it was not adaptable to checking purchased parts or subcontract parts in a receiving area. Magnegage-type instruments, which are now almost universally used, permit the checking of almost any part for any type of plating in any stage of manufacture or inspection. It is truly nondestructive in nature, even though we are prone to overlook it in current conversations dominated by more glamorous equipment.

Hardness Testers

The role played by hardness testers in the quality control of aircraft parts is too often overlooked, probably because they are so basic to our inspection operations. We do not normally think of a Rockwell or Brinnell tester as a nondestructive test instrument, until we realize that we are determining that specification ultimate tensile values are met without determining the tensile values directly by a tensile test. The general acceptance of the hardness tests by manufacturers has led to the development and use of a great variety of hardness testers, including Barcol, Webster.

FIG. 10.

Ames, Knoop, Vickers, Rockwell, Brinnell, and others based on the indentation principle, and most of which are used by Fairchild. Production schedules require the use of automatic hardness certifiers shown in Fig. 10 which are an adaption of a Barcol tester. Fairchild did much development work on this unit with the manufacturer. With the increased emphasis on high-strength aluminum alloys where the aging treatment increases the yield strength without too much effect on the ultimate strength, the use of hardness testers as we currently use them must be re-evaluated. Reference to Fig. 9 on 2014S will show the possible error if we consider hardness tests alone to be the criteria on materials properties. One of the points frequently overlooked is that currently used Rockwell conversion charts (readings vs. tensile strength) are based on steel research and are known to be inaccurate for other metals, such as brass, aluminum, and magnesium, even though we use them because we have nothing else.

CONCLUSION

This paper is not intended to provide a complete glossary of equipment, but it can be seen that we have a great array of nondestructive equipment and methods, many of which are new and for which we have yet to find the applications and limitations. These are the shining stars in our present and future, but we must not forget that, with the growing use of new materials and processes, it is extremely important that we periodically review our older nondestructive equipment and methods to see that their original limitations do not "falsify" results when used with new applications and materials. Fairchild Aircraft has a constant program of quality control laboratory testing and evaluations aimed at supplying inspectors with the best equipment available to do their jobs, which is to provide quality assurance to our principal customers—the military services. The intelligent, economic application of these nondestructive "tools" is one of the great jobs of any quality control program.

Silencing the Jet Aircraft

(*Continued from page 63*)

regions, and the reduction in aft cabin soundproofing for a given noise level all increase with increasing noise reduction.

The ultimate compromise for any particular airplane will be dependent on time, economics, and the continued technical improvements in noise suppression. One thing is certain from the results of the program so far—we can make significant reductions in the noise from jet aircraft without serious penalty to the aircraft performance.

Problems in the Design of Propeller-Driven Vertical Take-Off Transport Airplanes

(*Continued from page 75*)

[9] Kuhn, Richard E., *Investigation of the Effects of Ground Proximity and Propeller Position on the Effectiveness of a Wing with Large-Chord Slotted Flaps in Redirecting Propeller Slipstream Downward for Vertical Take-Off*, NACA prospective TN.

[10] Hammack, Jerome B., *Flight Investigation in Climb and at High Speed of a Two-Blade and a Three-Blade Propeller*, NACA TN 1784, 1949.

[11] Lovell, Powell M., Jr., and Parlett, Lysle P., *Transition Flight Tests of a Model of a Transport Vertical Take-Off Airplane with Tilting Wing and Propellers*, NACA proposed TN.

[12] McKinney, Marion O., Jr., and Drake, Hubert M., *Correlation of Experimental and Calculated Effects of Product of Inertia on Lateral Stability*, NACA TN 1370, 1947.

America's Capacity to Maintain Technological Leadership

(*Continued from page 41*)

If engineering education is to meet this challenge and reverse or even retard the spreading scarcity of quality in engineering schools that has weakened science teaching in high schools, it must find a way to make engineering schools a more attractive environment for top-flight engineers.

The success of engineering education in attracting and holding more first-rate teachers will depend mainly upon accelerating the development of more and stronger graduate programs. The graduate school and the research associated with it can provide engineer-teachers with the opportunities for professional activities and for growth as engineers which they now find chiefly in practice outside of educational institutions. In those engineering institutions where strong graduate schools exist and where there is a fruitful alliance with basic science, an environment satisfying to first-rate engineers has been better achieved.

While qualified Bachelor's degree recipients in engineering frequently go on for graduate study in other fields such as the physical sciences and management, the amount of advanced study in engineering still seems small compared to the advanced study *required* by law and medicine. The degrees are, of course, not comparable, but it is nevertheless of some significance that in 1953–1954 the number of advanced degrees in engineering, both Master's and Doctor's, totalled about 4,800 (of this total, only 594 were Doctorates) as reported by the U.S. Office of Education, while the total of M.D.'s and LL.B.'s was 6,757 and 9,898 respectively. Without dwelling on the impropriety of comparing apples and doughnuts, the implication is clear that the demands placed by our society on the engineering profession and on engineering education grow steadily greater and require advanced education more comparable to that in other professions.

There is also a growing conviction that the engineering curriculum must include a larger content of basic science, less traditional compartmentalization, and more emphasis on systems engineering and on such fundamental functional aspects of engineering as materials, thermodynamics, fluid flow, and energy conversion. The trend seems to lead toward a more generalized curriculum for all fields of engineering, with specialization deferred even to the graduate years or to the in-service training programs given by industry itself. Industry, acutely aware of its needs for engineers of more depth, power, and versatility, is encouraging these trends. Together, these new goals seem to forecast an increasing number of institutions dedicated to programs of high quality—programs that are less vocational and specialized at the undergraduate level and fundamental enough in their basic science and advanced enough in their mathematics and humanities to educate a new breed of engineer more adaptable to our advancing technology.

(3) The next plank in a platform for ensuring a flourishing technology calls for more attention to long-term objectives. There seems to be general agreement that we need a better balance between basic research and development—between fundamental ideas and hardware—and we are making only slow headway in achieving this better balance. Even though the President, the Hoover Commission, and other influential voices have emphasized the need for basic research, only about 7 per cent of the Government's research and development funds are allocated to this. According to a recent National Science Foundation study, only 2.4 per cent of the total research and development expenditures of the aircraft industry go for basic research, compared to 4 per cent for all industry and 10.5 per cent for the chemical industry. Along with the electrical equipment industry, the aircraft industry far exceeds all other industrial groups in the total expended for research and development. Nevertheless, it spends for basic research a smaller percentage of its total research and development budget than the average percentage for all industries.

I am fully aware that there are unavoidable reasons for this, but I respectfully suggest that, in an industry so dependent upon innovation and sophisticated technology and so receptive to new ideas, this imbalance should be a temporary one.

(4) We need better to protect and enhance the status of the scientist and engineer in our society. This is more than a matter of compensation, important as that may be; it is a matter of status and relative prestige in the array of professions. Too often now we find an attitude of antagonism toward scientists. The old cliché about the expert—that he should be on tap but not on top—is frequently applied in public circles to the scientist. Only rarely do we hear it said of the lawyer, banker, economist, or production expert—specialists all. I do not imply that the scientist has any right or unique qualifications to be on top. I am disturbed by the attitude that, because a man is a scientist, he is disqualified for public or private policy-making responsibility even though he may have the qualifications. We have multiplying examples in industry of the engineer or science executive, especially in the aircraft, petroleum, and chemical industries. The scientist and engineer, in their education and in their breadth of outlook, must also show that they can be first-rate specialists and still make managerial and other contributions to the common account of our society.

Great professional societies, such as the Institute of the Aeronautical Sciences, play an increasingly important role in stressing and augmenting the professional status of their members. The IAS plays an increasingly important role in cultivating the specialties of aeronautical equipment design and in not permitting individual specialties or disciplines to become inflated

out of all proper relationship to their place in the overall systems design or program. A great professional society has a responsibility to subject overly optimistic forecasts about technical performance to the test of sober, responsible judgment. The public has come almost to demand overly optimistic projections and to expect technical miracles. It may not be good for the professional status of the scientist and engineer passively to permit their work to be oversold.

(5) We must further present efforts to increase the Government's access to our national scientific resources by increasing the interaction between qualified members of the scientific community and Government officers carrying responsibilities for policy or operations affected by technology. The recent recommendations on research and development of the Hoover Commission are thoughtfully considered to achieve this objective, as well as a strengthening of the coordination of scientific activities at the top levels of Government.

The Government must have a root system which spreads over and draws sustenance from the entire civilian domain of science and technology. Thus our military technology can constantly respond to the rapid progress in basic science.

(6) The Government, in its contracting and budgetary procedures, should recognize still more widely than it does now the special nature of research and development. Contractual procedures designed for procurement are seldom appropriate for research, and short-term budgets are frequently inadequate for effective research. We need in every possible way to simplify the Government's management of research and development and to expedite its decision-making processes. . . .

(7) I come finally to the suggestion that we need a broadly conceived strategy for maintaining U.S. technological supremacy. I hope that the means and method can be found to undertake a thorough study of the factors involved in maintaining technological strength and removing the roadblocks to private initiative. I recall the great influence exerted by the Air Policy Commission through its notable report, *Survival in the Air Age*. We need a comparably thorough report to chart our technological progress in the years ahead. Such a report not only should deal with manpower and its education but also should look at the *utilization* of manpower and the personnel policies in Government, industry, and elsewhere which affect its efficient use and conservation. It should probe for soft spots in our research and development. Are there systems areas such as aircraft propulsion where we need more research effort? Are there fields such as metallurgy—and overlapping fields such as design and fabrication involving mechanical engineering and metallurgy—where we need more manpower and more development? Is not the whole area of materials one which warrants new and more massive effort? Is there now too much loss of time between discovery and application?

These are but a few of many questions which could be fruitfully examined in the context of a study devoted to "Survival in the Age of Technological Contest."

If such studies should be amplified by a civilian team of adequate size, competence, and imagination, and with all doors opened for data by Government and industry, the results might well become a major document of state, as well as a blueprint for maintaining America's technology as an impregnable shield and as a mighty multiplier of our wealth and well-being.

The Floating Integrating Gyro and Its Application to Geometrical Stabilization Problems on Moving Bases

by C. S. Draper, W. Wrigley, and L. R. Grohe

Now Available as a Sherman M. Fairchild Fund Paper No. FF-13

This paper as presented in this form represents a considerable revision of the preprint version. In particular, the text and illustrations that pertain to experimental results of gyro unit tests have been given careful attention, with the object of presenting a truer picture of the relative performance capabilities of integrating gyro units, rate gyro units, and feedback integrating gyro rate indicating systems.

Member Price $1.00 **Nonmember Price $1.50**

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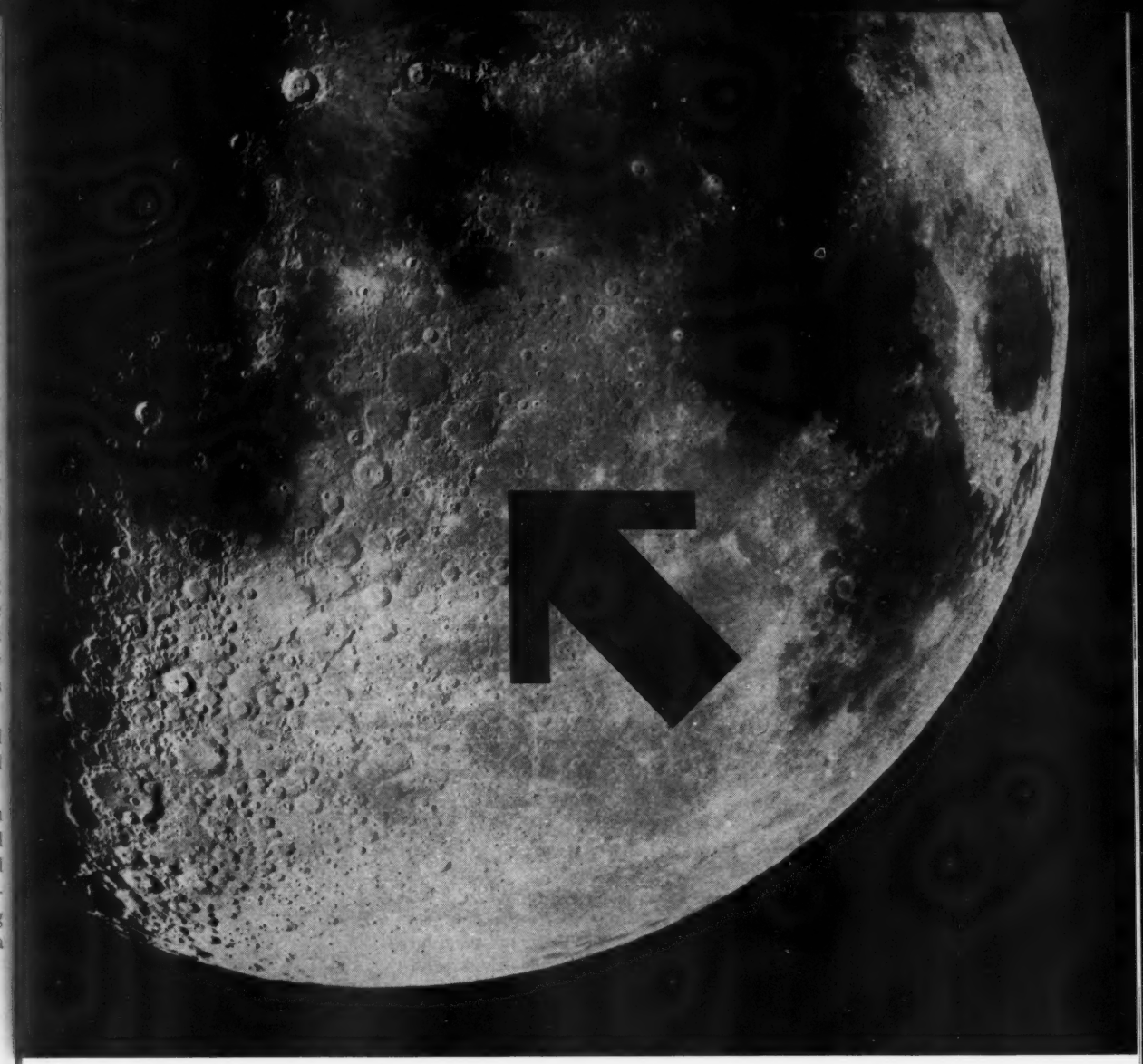

NEW FRONTIER

"If we had to put a man on the moon, we could do it."
– Overheard at an Institute of Aeronautical Sciences luncheon

This impromptu statement was not a matter of idle conjecture. It was a statement of a positive and scientific fact – as provable as if he'd said the Aleutian Islands – and contingent only upon three prime requisites: enough time, money, and necessity. And by "we" he meant today's mindpower and facilities operating under the most advanced concepts of research and development.

Those concepts as practiced at Martin today would be essential to the fastest possible solution of any complex flight systems problem now within the capacity of man to solve.

It is this that has established Martin as one of the prime forces in the coming conquest of the new frontier – Space itself.

MARTIN
BALTIMORE

24th Annual Meeting—
Summary of Technical Sessions

(*Continued from page 47*)

those which make major contributions to the field. Various societies are now struggling with this problem.

The paper concluded with a plea that the consumer, or employer of engineers, continue the training of the graduate and, above all, use him effectively. The presentation of this paper was frank and perhaps blunt in some regards and represented a constructively critical attitude which the educator needs to assume.

A panel discussion followed the formal paper presentation with questions from the floor directed to the speakers. Considerable interest was evidenced by audience participation. Approximately 100 persons attended, about one-third from education and the balance from industry, research, and other fields. The education of engineers is an extremely important current problem. The Institute is commended for its active interest, making this informative session possible.

Air Space Use

by
J. Francis Taylor, Jr.
Director
Air Navigation Development Board
Civil Aeronautics Administration

The session on air space use was intended to show, first, how we are presently using our air space; second, the forecast and nature of air transportation for the next 10 years; and, last, what improvements could be expected so as to permit the growth that had been forecast.

In a paper on the "Distribution and Movement of Air Traffic in the Boston, Salem, and Hartford Sectors of the Boston Air Route Traffic Control Center, August 3, 1954," Charles I. Stanton and Kenneth van Wymen, of the Bell Telephone Laboratories, showed by a unique plan presentation developed at the Bell Laboratories what an actual traffic situation looked like in the Boston area. This was intended to provide the background, by illustration, of traffic control as it is at present.

The Bell Laboratories, under joint sponsorship of the Air Navigation Development Board and the American Telephone and Telegraph Company, has made a study of the air route traffic control system. Attention was focused on the movement and distribution of IFR traffic and the related communications in the Boston area.

A projection type of display was shown to illustrate this study, which gave the plan position of every aircraft in the area. Aircraft position and heading were indicated by an arrow, identity was given by a 3-number code above the arrow, and altitude by a 3-number group below the arrow. The maximum number of aircraft in this en route area at one time was 32. If these had been distributed along the 1,000 miles of airways at the six most used altitudes, the average separation of aircraft at the same altitude would have been about 190 miles.

It was found that the time required to handle the land line communications in the three busy control sectors of the area would require 70, 55, and 49 per cent of the time available to the controller in the respective sectors. One of the sectors used radio, as well as land line communication. This occupied 31 per cent of the time available to another controller.

Data from the three sectors of the Boston area indicate that a controller is not likely to impose delays upon aircraft until communications take about 40 per cent of his available working time. Thereafter, the delay time increases rather rapidly, and 50 per cent may be selected as the criterion for the desirable upper limit of a controller's work time that should be devoted to communications.

On the average, there were about 2 min. of controller communications for each air-borne flight. On the basis of the 50 per cent criterion of the previous paragraph, a controller could handle about 15 air-borne flights per hour with moderate delays. This would mean an average of about five air-borne flights at a given moment of time within the area of a single sector.

The study leads to the conclusion that delays to aircraft movements result from the communication load which the system places on the controller and not from lack of physical airspace.

A. D'Arcy Harvey, Planning Officer of the Civil Aeronautics Administration, by his presentation of "Air Traffic Facts," showed the growth of aviation for the next 10 years as anticipated by the CAA.

The CAA study of air transportation showed that three basic population-air traffic relationships exist:

(1) The distribution and concentration of population within the continental United States establish the pattern and control the apportionment of air traffic in and between communities.

(2) A community's population size and economic character fix its volume of terminal air traffic.

(3) The flow of air traffic between pairs of communities varies directly with the size of their population product and inversely with the distance between them when due allowance is made for such secondary factors as (a) differences in the air/surface distance ratio, (b) minimum effective distance for the present-day aircraft, (c) the economic character of each community in a pair, and (d) the density of communities within a geographic area.

Terminal Air Traffic—All types of air commerce traffic are concentrated in the air traffic hubs. Air traffic hubs are defined as Large (1 per cent or more of total enplaned passengers in the United States), Medium (0.25 to 0.99 per cent), Small (0.05 to 0.24 per cent), and Nonhub (less than 0.05 per cent). In fiscal year 1955, the hubs had 79 per cent of the domestic air carrier departures, 95 per cent of the passengers, 96 per cent of the mail, and 97 per cent of the cargo. Significant concentrations do not, as a rule, occur in nonhub locations, particularly those without air-line service.

En Route Air Traffic—CAA has complete, excellent data on all IFR en route air traffic which is unique because similar facts are not available on a nationwide, recurring basis for other forms of transportation. The VFR en route air traffic facts are sufficient for general and military aviation and excellent for air commerce. The IFR pattern serves well as an indicator of the VFR pattern also.

Actual counts of en route traffic demonstrate that significant nonstop en route volume normally requires that one or both communities be an air traffic hub. Furthermore, high density airways usually link large air traffic hubs with each other or one of the five giants (New York, Chicago, Washington, Los Angeles, and San Francisco) with nearby medium and small air traffic hubs.

The use of en route air traffic facts permeates CAA's planning but is most evident in the Federal Airway Program. CAA's Airway Planning Standard No. 2 and the Federal Airway Plan are prime examples.

Air Traffic Forecasts—The CAA believes that a 1960 forecast of 55 million passengers and a 1965 forecast of 70 million passengers are realistic for the domestic air lines. If helicopters effectively develop the true short-haul market, these forecasts may be too low.

Anticipated developments in aircraft design plus a number of significant long-range trends in the American economy point to further healthy expansion in business transportation by general aviation aircraft. It is esti-

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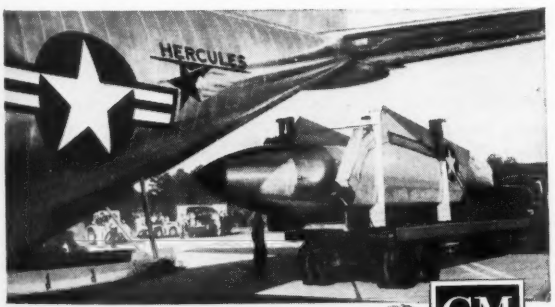
Lockheed C-130 Hercules to provide jet age transport speed with Allison Turbo-Prop Engines and Aeroproducts Propellers

Now in production at Government Aircraft Plant No. 6, Marietta, Georgia, the Air Force's first turbo-prop transport before long will begin active service with the USAF Tactical Air Command.

Powered with four Allison T56 engines and Aeroproducts Propellers, the new Lockheed Hercules will add speed and load-carrying ability to the logistics support of our jet-powered combat forces.

Now undergoing the rigid test of cold weather operation in the climatic test hangar at Eglin AFB—home of the Air Proving Ground Command—the C-130 will be proved fit and ready when it reports for duty some time this year.

Already the matched team of Allison engines and Aeroproducts Propellers stands as the most thoroughly proved turbo-prop power package in America. In military – as well as in commercial service – it is ready to take its place in the jet age of air transportation.



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AMERICAN BUILT FOR THE JET ERA IN AIR TRAVEL

mated that business flying will climb to 5.7 million hours by 1960 and should total 7.2 million hours by 1965—almost double the 1953 volume.

Air carrier aircraft have accounted for the bulk of all instrument approaches year after year, but their role has been a declining one. This proportionate decline in air carrier activity was offset by an increase in military instrument approaches. In the future, aircraft should make greater use of the airways' facilities. A 1960 forecast of 900,000 instrument approaches and one of 1,200,000 by 1965 fit the expected growth pattern.

In "Common System Development, 1956" James L. Anast of the Air Navigation Development Board described the program and philosophy of development by which it was hoped an expanded traffic-control capability could be promised the rapidly growing aviation industry.

The reorganized Air Navigation Development Board has been in existence for nearly 2 years. In answer to the question, "What is the outlook for the common system?" optimism was expressed on the approaching jet age. Mr. Anast predicted that giant strides would be made in air navigation and traffic control.

He cited the practically unlimited technological advances on which to draw and the apparently unanimous desire by all elements of aviation to speed up progress. The ANDB plan represents a modern "system" approach to the problem, involving, operational analysis, use of "Monte Carlo" simulation techniques, one-to-one time simulation using human beings in the system, and extensive system experiments. It was his opinion that prior attacks on the development of air navigation and traffic control were piecemeal and, therefore, doomed to failure. The present approach is drawn from the successful experience of the developers of other comparable systems, such as the air weapons system.

Mr. Anast predicted that radar would be the means by which initial advances will be made in the capacity of the common system. He referred to the tremendous automatic tracking capacity of the semiautomatic ground environment being developed by the Air Force and predicted that fairly complete physical integration would take place between air traffic control centers and air defense centers, as well as cooperation in the form of exchange of data between systems. Mr. Anast pointed out that the corollary "nontechnical" problems have been the most difficult and will continue to be so because of the necessity of streamlining the Government organizations and the lack of adequate research and development facilities focusing on the common system.

Air Transport

by
Harold D. Hoekstra
Chief Project Officer
Aircraft Engineering Division
Civil Aeronautics Administration

The air transport session opened with a paper by H. I. Rothrock, Special Assistant to the Head of the Air Navigation Aids Branch, Office of the Chief of Naval Operations Department of the Navy. His subject was "Navy Requirements for Air Navigational Aids, Communication Facilities, and Air Traffic Control, 1955–1975."

The mission of the Navy, Mr. Rothrock pointed out, requires that it base and operate aircraft on and over both land and water. These requirements, unique with the Navy, give rise to rigorous requirements in the fields of air navigational aids, communications, and air traffic control.

The existing system of navigational aids in use ashore not only requires a multiplicity of air-borne equipment but does not permit of installation afloat. Navigational accuracy in the civil or "Common System" ashore falls far short of the accuracies required in the tactical system afloat. In addition, it is required that any short-range navigation system, to be usable afloat, must permit all of its components to be installed on a single ship. This cannot be accomplished using Common System components.

The existing system of civil air traffic control fails to make adequate provision for the expeditious movement of high-performance military aircraft. Delays to operational training and other military flight operations within continental United States are serious, and adequate efforts to rectify this situation have not yet been made.

There is a pressing requirement for a completely integrated Common System of aids to air navigation, communication, and traffic control, suitable to the needs of both military and civil operators and so designed that it will be acceptable to all users of the airspace.

In the discussion of Mr. Rothrock's paper, Jerome Lederer of Flight Safety Foundation raised the question of protection against ground power failure, and the speaker agreed that stand-by systems were essential.

Captain Ralph Barnaby USN (Ret.), suggested that the function of the Air Navigation Development Board be explained, whereupon Mr. Rothrock outlined the composition and duties of this interdepartmental board (with representation from Defense, Commerce, Air Force, Navy, and Army) which is charged with the overall responsibility for the coordination of the development of Common System aids.

James Pyle, Special Assistant for Civil Aviation, Navy Department, stressed the importance of having all interested parties assist the CAA in the implementation of the agreed upon programs, particularly in support before the Bureau of the Budget and the Congress.

A. C. Campbell Orde, Operations Development Director, BOAC, pointed out that BOAC and European experience showed that more work is needed on a policy for long-range aids and that careful coordination is required with such systems as Mr. Rothrock had discussed.

In the second paper, Irving I. Gringorten, of the Air Force Cambridge Research Center, outlined a method of optimum flight planning and navigation and described the associated meteorological procedures. He also made recommendations with respect to optimum operations of transport aircraft, both civil and military.

Thomas L. Burkett, of Cook Research Laboratories, was coauthor of the paper entitled "Integration of Weather Forecasting, Flight Planning, and Flight Watch."

As long as 10 years ago, the advantage of pressure pattern flying was demonstrated in savings of transatlantic flying time. Aircraft whose courses were altered to gain a wind advantage were able through savings of en route fuel to carry, on the average, 10 per cent greater pay loads. But there have been difficulties, both real and inescapable, or circumstantial. Domestic and international flying regulations have been designed primarily for fixed route operations rather than for optimum routes. Although there are provisions for direct flights in Civil Air Regulations, traffic control and restricted area problems prevent the full utilization of optimum techniques. The representation of forecast and en route weather and the difficulty of calculating the optimum headings and altitude have been deterrents.

Since October, 1954, the Atlantic Division of the Military Air Transport Service has been making increasingly frequent use of minimal flight plans, using a technique that is quickly taught to operations and flight crew personnel and easily integrated into flight operations. The optimum flight planning procedures not only provide

more pertinent information for flight operations but also provide for in-flight correction of flight plans based upon later-observed weather information. It has been one of the important advances toward optimum aircraft operations.

Walter Bohan of Cook Research Laboratories took part in the discussion in the absence of the coauthor, Mr. Burkett. The questions raised related to accuracy of position, which Mr. Gringorten indicated was fully as good as with other methods; extension of the system to aircraft without navigators, answered in the affirmative; and finally, possible timesaving, which the author felt could be up to 10 per cent.

"The Turbine-Propeller Combination in the Air Force" was the topic of Lt. Col. Roy J. Wellman, USAF, of the Directorate of Research and Development.

In spite of the fact that transport aircraft cruise nearly 400 m.p.h., Colonel Wellman said, the movement of large quantities of goods over long distances is still accomplished at a speed "little better than that of the covered wagon."

One of the biggest factors in reducing the time from point of origin to destination is to have aircraft with greater nonstop ranges together with the ability to get into and out of the maximum number of different airfields on a global basis.

The turbine-propeller combination is admirably suited to meeting the need for shorter take-off and landing distances, greater ranges with higher speeds, and reduced specific fuel consumption at less overall system cost.

A specific comparison was made of the same airplane powered with turboprops and with turbojets to show graphically the areas of performance that the propeller improves. In place of the propeller, a fraction of this improvement could be obtained by using 30-1000# JATO bottles per take-off. For landing, one chute could be used on the glide path and one for landing roll. Despite this, the difference must be made up with tons of concrete. And finally, in the air a duplicate system of fueling must be used in order to obtain range.

A second comparison showed the specific fuel consumption that can be achieved with the turbine engine through use of higher turbine temperatures. A third comparison showed what is expected from theory in the form of propeller efficiencies at increased speeds.

The work is being carried on by the NACA in XF-88B tests and by the Air Force with two F-84H airplanes. A third project is the XB-47D airplane. Colonel Wellman invited those with a need to know and proper clearance to discuss these projects further with

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Modern submarines, able to make long voy… while completely submerged, and to lau… nuclear missiles in a sneak attack, are am… the most sinister weapons of this atomic a…

To safeguard our nearly twelve thousand mi… of coastline against sub invaders, the U.S. Na… for ten years has patrolled immense areas… the ocean, in fair weather and foul, in Lockh… P2V *Neptunes*. Special submarine detec… gear enables the P2V, despite darkness or f… to pinpoint even submerged subs. And p…

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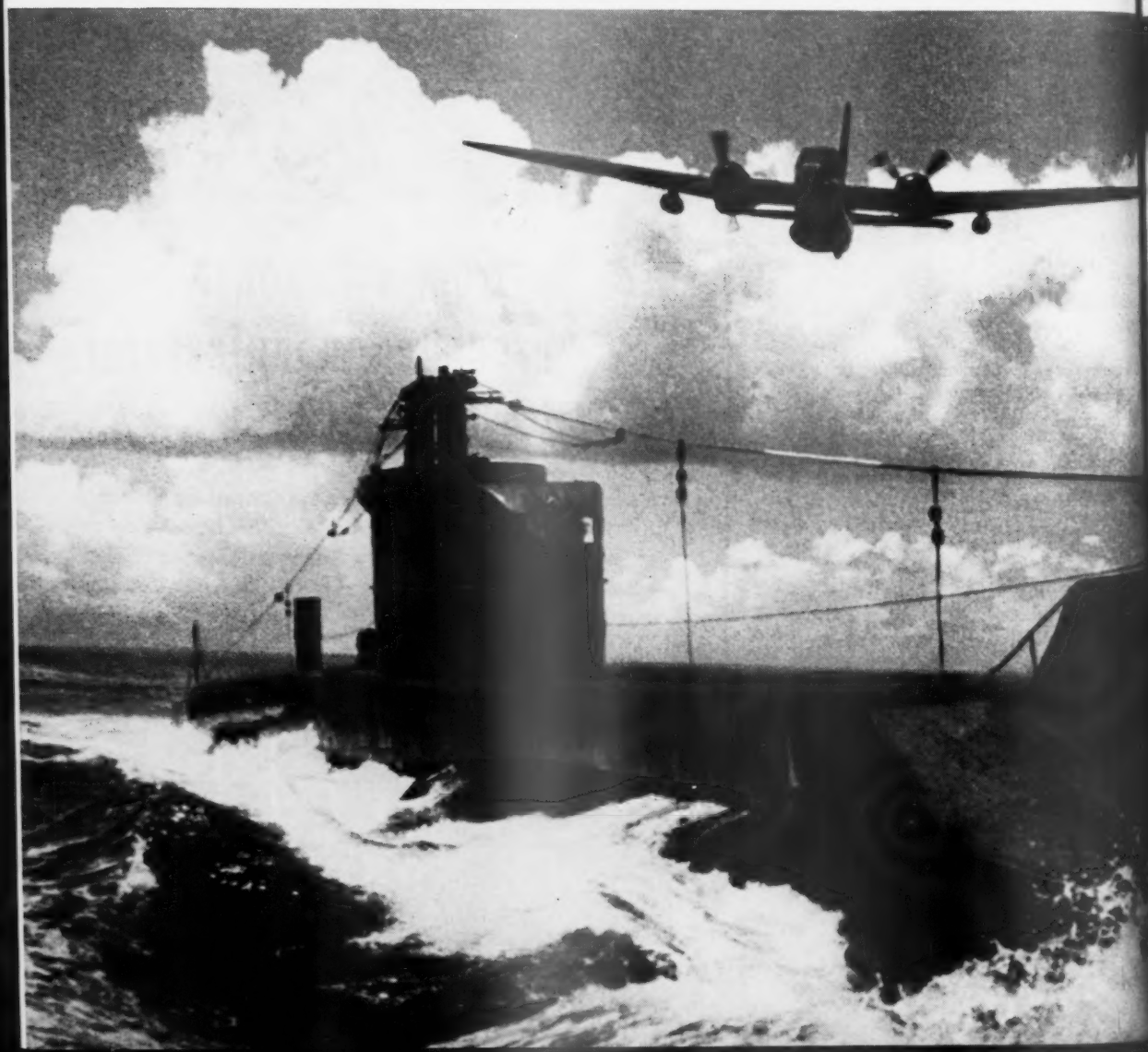
A CRUCIAL U.S. DEFENSE PROBLEM

Official R.A.A.F. photo (below) shows war games "attack" on British sub by Royal Australian Air Force *Neptune*. (P2V's a… in military service for the following friendly countries: Australia, Canada, Great Britain, France, Japan and the Netherlands…



ressive modifications of the P2V have kept it
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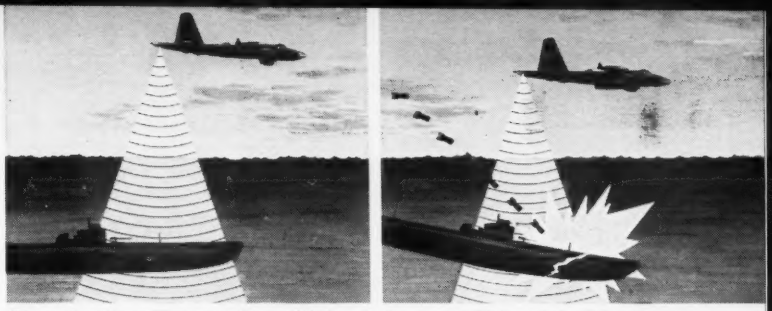
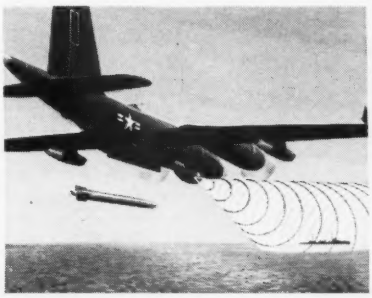
ound for pound, and dollar for dollar, the
2V *Neptune* is the most formidable patrol
ircraft bearing the insignia of the U.S. Navy.

Recently the Navy awarded Lockheed its *24th* contract for P2V *Neptunes*—a tribute to Lockheed's leadership in weapons system management, the development and application of electronics, and the design and production of long-range patrol aircraft.



These drawings illustrate the multiple-mission capabilities of the P2V *Neptune:* **1** Low-flying P2V's electronic gear spots submerged sub because its presence distorts the earth's magnetic field. **2** Depth-bombing a submerged sub, **3** torpedoing a surface ship or laying mines to disrupt enemy shipping are jobs the P2V can do equally well. **4** Spotting hurricanes and reporting their velocity and direction are routine but important P2V missions which save human lives and vast sums in property damage.



Lockheed Missile Research Laboratories to Be Built in Stanford's Industrial Park

A series of research laboratories will be constructed by Lockheed's Missile Systems Division on a 22-acre site adjacent to Stanford University, Palo Alto, California. On a nearby site of 275 acres, at Sunnyvale, Lockheed will build extensive new engineering, manufacturing and administration facilities. Lockheed's 3,000 scientists, engineers and technicians now developing guided missiles and unmanned aircraft at Van Nuys will transfer to Palo Alto and Sunnyvale as rapidly as construction permits.

The proximity of both new sites to Stanford will make the university's outstanding academic resources available to Lockheed research teams. And the new laboratory facilities to be built by Lockheed will provide Stanford scientists with technological tools and consulting opportunities hitherto unavailable.

ATTENTION, STUDENTS WHO DESIRE MASTER OF SCIENCE DEGREES: Lockheed's Advanced Study Program *helps students achieve MS degrees in Mathematics, Electrical and Mechanical Engineering, Aeronautics and other physical sciences. Write:* LOCKHEED MISSILE SYSTEMS DIVISION, *Van Nuys, Calif.* *(Below: aerial photo of Stanford campus.)*

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Government agencies, Air Force people, or with the contractors involved.

Following the presentation of papers, a film was shown illustrating the Boeing B-47D, which mounts Wright T49 propeller turbines in place of the dual J47 inboard jet pods.

The discussion opened with a question from William D. Perreault, of Lockheed-Georgia Division, concerning the make of propeller on the B-47D; this is a Curtiss. Another question was asked about the relative advantages of turbofan and turboprop engines; Colonel Wellman pointed out that one of the main advantages of the turboprop was earlier availability.

In answer to a question as to the increase in range given the B-47 by turboprop engines, Colonel Wellman pointed out that it was too early to reach definite conclusions but that study of curves in the paper might indicate 30 per cent increase for the turboprop.

R. M. Woodham, of the Cornell-Guggenheim Aviation Center, asked about free turbines, but the speaker indicated that he did not have information available at this time.

Aircraft Design

by
Richard G. Bowman

Assistant Chief Engineer
Republic Aviation Corporation

The session on aircraft design was opened with a paper by James L. Decker, in which he presented a method, based on theoretical considerations, for estimating the downwash angle for various tail locations. The modern airplane with swept-back wings has shown that its stability characteristics are extremely sensitive to the location of the horizontal tail. This is particularly true at low speeds. The problem of tail location becomes more acute as the aspect ratio decreases. Knowledge of the downwash is a vital necessity in the preliminary design stage when valid and rapid approximations are required before the design has reached the stage where wind-tunnel results are available. The paper compared predicted results with actual wind-tunnel test data to show good agreement between the predicted and test results. The importance of this paper was illustrated by the last figure which indicated that a poor location in the downwash field can reduce the tail contribution to zero.

The agreement between the test results and the estimated values was sufficient to discourage any extensive discussion. All agreed that the topic was of current interest and a useful tool in preliminary design. The author and the chairman engaged in a discussion to indicate that such items as nacelles or air intakes in the leading edge of the wing could greatly disturb the downwash field and that these possibilities should be kept in mind.

M. A. Sant Angelo presented a paper on "Integrated Flight Equipment System with a Primary Emphasis on Instrumentation and Controls." In this presentation, the pilot is considered to be a part of a closed loop control system in which he receives information from instruments and then performs the necessary action to control the airplane. As our flight speeds increase, less time will be available for the pilot to make the necessary decisions and control motions. This lack of time leads us to use automatic pilot systems which can measure and act faster than the human pilot. The human pilot, however, is still considered to be in charge of the flight and is referred to as the flight manager. In his position as manager of the flight, he must monitor the actions of the automatic controls by reference to numerous measuring instruments. This paper shows a need for instrument systems which will collect and integrate these measurements so that the pilot can obtain his information from fewer sources and by methods which will simplify his need to interpret and compute the meaning of the measurements.

The discussion indicated that all were in general agreement with the need for integrated systems to collect and display information, but some members, and particularly the chairman, expressed the opinion that much more effort is required in the presentation of the information so that the pilot can assimilate the information quickly and with a minimum of effort and least possibility of error. As speeds increase, it will be necessary to give the automatic flight control systems more and more authority, since there will be a larger flight regime in which the human pilot is just too slow. In addition to rapidity of action, the requirements will call for large aerodynamic forces to be exerted by the controls.

I prefer to think of the human pilot as the supreme boss and the automatic control system as his assistant. I shall continue to think so, for at least a little while to come. This philosophy poses the problem: "How can a human pilot monitor and control an automatic system that can measure and react more precisely and faster than the human pilot?" This will be a difficult and pressing problem, which must be solved in the near future.

The paper on "Reverse Thrust, Vertical Lift, and Side Force by Means of Controlled Jet-Deflection" was presented by Leonard Meyerhoff. The use of reverse thrust has many advantages in a turbojet-powered airplane. This is particularly true because of the higher landing speeds and clean low drag configuration of the modern jet. The paper presents the analytic basis for calculating the effect of jet thrust for use as a brake and to evaluate the power of the jet as a device for producing side thrust and other control forces. Numerous curves are used to illustrate the effects of the deflected jet when operated as a brake in various flight conditions, ranging from high speed to approach speed, and during the landing roll. The calculations show the effect of delayed application of reverse thrust on the landing roll distance.

The use of reverse thrust as a means of controlling the landing approach and ground roll is being energetically studied by those engaged in commercial jet aircraft. The application of a controlled jet deflection to augment the power of the air controls is being considered in many of the newer designs of high-performance aircraft and missiles.

Aircraft Noise

William Littlewood, Chairman

Vice-Pres., Equipment Research
American Airlines, Inc.

Four papers were presented at the aircraft noise session. The first was "Noise, Vibration, and Aircraft Structures" by Arthur A. Regier, Head of the Vibration and Flutter Branch of NACA Langley Aeronautical Laboratory.

With the availability of larger power plants, Mr. Regier said, the problem of noise fatigue has been aggravated to the extent that noise damage to structural areas near the propellers and jets is becoming an important consideration in the determination of aircraft configurations. He discussed the subject in four parts: (1) response of systems to various types of inputs, (2) near field characteristics of various noise sources, (3) vibration modes, and (4) fatigue.

Pressure fluctuations in the order of 180 db. or $1/4$ atmosphere are produced near present propulsive systems and on aerodynamic surfaces subjected to shock buffeting. Most aircraft skins and

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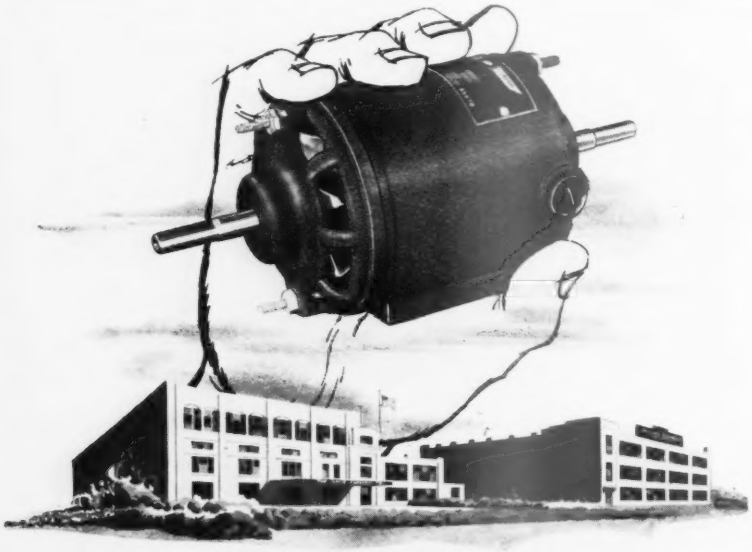
secondary structures will show fatigue damage after many cycles, when subjected to pressures ranging from 140 to 150 db., and permanent set or rupture after short exposure to 180 db.

Horace O. Parrack, of Wright Air Development Center, spoke on "Noise, Vibration, and People." He presented a general method of attack utilizing the elements of a functional system essential in seeking solutions to the problems involved. He outlined the quantitative data about each element and described the known information about how people respond to acoustic energy (noise). Then the system, including "sources," "transmission paths," and "men as receivers" was discussed with respect to its application to problems created by the noise from air operations.

Charles T. Molloy, of Lockheed Aircraft Corporation, delivered a paper on "Noise, Vibration, and Aircraft Equipment." He discussed noise caused by reciprocating-engine power plants, jet engines, and machinery. He also discussed the efficacy of floor coverings for the reduction of airplane vibration and the capability of acoustically lined ducts to reduce aircraft ventilation noise.

"Silencing the Jet Aircraft" was the title of a paper by Holden W. Withington, of the Boeing Airplane Company. The Boeing 707 commercial jet transport, he said, will incorporate a noise-reduction device which will substantially reduce the external jet noise with only minor degradation of performance. Technical progress has been achieved which will result in the 707 being actually quieter, from the airport and surrounding area standpoint, than some of the present propeller-driven transports.

The paper described the development program currently in progress at Boeing covering all phases of the noise-reduction problem. It discussed (1) acoustical characteristics, (2) effects on engine performance and operation, and (3) effects on airplane performance. Results were given in terms of noise reduction, thrust coefficients, and airplane drag characteristics for a large number of model and full-scale configurations. The work was summarized by showing noise contours around a typical airport for the 707 in comparison with present propeller transports.*



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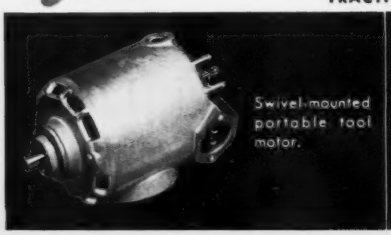

Swivel-mounted portable tool motor.

Aircraft de-icing pump motor.

Earth Satellites

by
Paul Rosenberg

President, Paul Rosenberg Associates
Consulting Physicists

Man-made, earth-circling satellites stir the imagination of even the most conservative scientists and aeronautical engineers. This

was strikingly demonstrated by a record attendance at the IAS earth satellite session and by the quality of the audience's serious, factual questions concerning this otherwise sensational subject. An authoritative, sober account of the earth satellite program was presented by a panel of four speakers, all of whom have been responsibly and intimately engaged in the actual planning and direction of the earth satellite program, which promises to be one of the great scientific achievements of our time.

Future historians are likely to say that the first earth satellite is to space travel what the Wright brothers' flight at Kitty Hawk is to present-day aviation. Nevertheless, these two historic events will differ in three significant ways:

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* "Silencing the Jet Aircraft," by Holden W. Withington, appears in full in this issue on pp. 56–63, 84.

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(1) The flight at Kitty Hawk was made in relative obscurity; those few newspapers that described the first flights did so with sceptical and preposterous statements about the Wright machine. By contrast, the first earth satellite will be launched in the full glare of the most widespread and accurate advance publicity that has ever been given a scientific experiment.

(2) The first two times the Wright brothers offered their airplane and their services to the U.S. Government, they were completely rebuffed. By contrast, the first earth satellite will be launched with the complete support and cooperation of our Government.

(3) The Wright plane was essentially the work of two men, whereas the earth satellites will be the cooperative work of an extremely large number of men in a joint effort of Government agencies, the Armed Services, university scientists, and industry. Indeed, the scientific observations to be made with the earth satellites will enlist the aid of scientists throughout the world.

The relation of the earth satellite program to the world-wide scientific effort of the International Geophysical Year 1957–1958 was described in broad perspective by Dr. Joseph Kaplan who delivered the first paper on the program. Speaking authoritatively as Chairman of the U.S. National Committee for the IGY (under the National Academy of Sciences), Dr. Kaplan related the significant events that led up to the July, 1955, White House announcement of the intention of the United States to launch a series of earth satellites beginning approximately in June, 1957.*

Hundreds of sounding rockets will be fired in many parts of the globe for upper atmosphere research during the IGY, some of these being high-performance Aerobees capable of ascending approximately 200 miles. Nevertheless, the results of such rocket soundings are limited because the total flight time spent in a particular altitude range is extremely short and because the flight paths have only limited geographic coverage. A satellite vehicle, by contrast, can give synoptic data over large areas of the earth, over relatively long periods of time, and at high altitudes. Dr. Kaplan has aptly called the earth satellite an LPR (long-playing rocket).

It is obviously an interesting and difficult problem to launch and guide a satellite vehicle, at a speed of approximately 18,000 m.p.h., into a prescribed orbit lying 200 (perigee) to 800 (apogee) miles above the earth's surface. However, only general engineering information concerning the launching and guidance could be released at the time of the IAS session on earth satellites. Consequently, the session was devoted principally to the scientific utility and research significance of the satellite vehicles, topics indeed of broader interest than the launching and guidance.

The earth satellites will be used for the following scientific purposes, among others (the sequence of this listing is not significant): observation and measurement of solar and cosmic radiation; study of ionized layers of the atmosphere (which affect radio transmission); investigation of the aurora and air glow; study of the magnetic field in the vicinity of the earth; study of meteoric dust; measurement of density, temperature, movement, and chemical constitution of the upper atmosphere; measurement of the shape of the earth and the distribution of mass within the earth; and accurate measurement of intercontinental distances.

Measurements and observations of at least the first four types listed above must be made by automatic instruments carried in the satellite and the results telemetered to ground stations. Scientific observations of this type, using instrumented satellites, were discussed at the session in a paper by Dr. J. A. Van Allen, Chairman of the Department of Physics, State University of Iowa, and Chairman of the Upper Atmosphere Rocket Research Panel, the group that has planned and guided all upper atmosphere rocket research in the United States in the past decade. In pointing out the tremendous advantages of the LPR for upper atmosphere research, as compared with conventional high-altitude rockets, Van Allen commented that one instrumented earth satellite could give him, in the course of a few days' successful operation, more significant cosmic ray data than he has been able to accumulate in a decade of laborious scientific expeditions to various parts of the globe.

The instrumentation problems of the satellite are obvious from the simple facts that the vehicle will have a diameter of 30 in. or less and a total weight of 21.5 lbs., about half of which will be the sphere itself. The 10 lbs. available for instrumentation must include the sensing and measuring instruments themselves, a telemetering transmitter, a command receiver, and a source of power—all built to withstand acceleration and a wide range of temperature and pressure conditions.

When the satellites re-enter the denser portions of the atmosphere at high orbital speeds, they will disintegrate in much the same way as small meteors. The life of the satellites will be of the order of magnitude of several days to several months, depending upon their orbits and upon the densities encountered in the upper atmosphere. The practical engineering problems of recovering the satellites are so formidable that no attempt at recovery is contemplated in the present satellite program.

Many important measurements can be made by observing the orbital motion of an "inert" satellite—i.e., a satellite with no instrumentation. For example, atmospheric drag on the satellite is a sensitive measure of atmospheric density as a function of height, a function that is now not accurately known for the upper atmosphere; the earth's shape and the distribution of mass within the earth will also affect the motion of the satellite; accurate measurements of intercontinental distances are possible by optical and radar observations from ground stations. These types of measurement and observation with an inert satellite were discussed at the session in a paper by Dr. Fred L. Whipple, Director of the Smithsonian Astrophysical Observatory, Professor of Astronomy at Harvard University, and a member of the U.S. National Committee Technical Panel on the Earth Satellite Program.

Twelve or more specially equipped stations at strategic points around the earth will be assigned the main task of observing satellite positions by precise photographic measurement. In addition, a world-wide corps of amateur astronomers will be enlisted to assist in tracking and locating the satellites. Observations by the amateur astronomers will be most useful during a satellite's first 90-min. circuit of the earth when the initial orbit must be found and again in the last few circuits of the satellite's life when the orbital changes are rapid.

The frequently quoted statement that the satellite will be visible to the naked eye gives rise to a popular impression that anyone in the street, so to speak, will be able to look up and see the satellite at his convenience. Such is not likely to be the case. The brightness of the satellite will probably be near the limit of naked-eye sensitivity, so that the following conditions must be met for naked-eye visibility: The satellite must be near its perigee; it must be seen almost vertically; the sky must be clear; and the earth's surface at the observing post must be in twilight. Simple optical instruments—e.g., an amateur astronomical telescope—will of course aid observations considerably.

The 3-year project of building and launching the satellites, entitled Proj-

* "Rocket and Satellite Studies During the IGY," by Joseph Kaplan, appears in full in this issue on pp. 64–67.

ect VANGUARD, has been undertaken by the Department of Defense, within which the Navy heads the program. Project Vanguard was described in the concluding paper of the session by Rear Adm. F. R. Furth, USN (Ret.), (now with Farnsworth Electronic Co., I.T.&.T.), who, until his recent retirement, had overall responsibility for the project in his capacity as Chief of Naval Research. Admiral Furth presented several newly released items of engineering information concerning the program, plus the fact that the launching site of the first satellites will be Patrick Air Force Base, Cocoa, Fla.*

The satellite will be launched by a three-stage rocket. The Glenn L. Martin Company, prime contractor for construction of the rocket, has awarded a subcontract to the General Electric Company for the construction of the first-stage rocket motor, which will have a thrust of 27,000 lbs. at sea level, and an operating time of 140 sec. The first-stage rocket will be an improved Viking with its fins removed; the rocket will be stabilized by the thrust of the motor, gimbal mounted.

The second-stage rocket will be constructed by the Aerojet-General Corporation and will also have a finless, cylindrical air frame of monocoque construction. In order to prevent excessive aerodynamic heating of the satellite itself (the pay load), it is likely that the satellite will be sheltered with a conical nose to be jettisoned at the end of the second stage. The third stage will have a solid propellant motor and will have a spin imparted to it.

A year and a half of further planning, development, and construction remains before the first satellite is launched. Nevertheless, the principal features of the program have been determined, and most of them are likely to stay the same as they were when presented at this first session on the subject of earth satellites.

When the first man-made satellite hurtles into its orbit in 1957, we will have reached an important milestone in the eventual conquest of interplanetary space.

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*"Project VANGUARD—The International Geophysical Year Earth Satellite," by Rear Adm. F. R. Furth, USN (Ret.), appears in full in the March, 1956, issue of the AERONAUTICAL ENGINEERING REVIEW, pp. 55–59.

Electronics

by
H. Guyford Stever

Chief Scientist
United States Air Force

The session on electronics was presented in cooperation with the Institute of Radio Engineers and the Radio Technical Commission for Aeronautics. Inasmuch as the scheduled chairman arrived late because of air transportation difficulties, Dr. K. C. Black of the IRE pinch-hit at the opening of the meeting.

The first two papers on the program dealt with the important and practical subject of the cooling of electronic equipment in high-performance aircraft. Though both authors, J. B. Welch of the Cornell Aeronautical Laboratory and Nathan A. Carhart of the Douglas Aircraft Company, approached the subject matter broadly, the two papers were in large measure complementary, for Mr. Carhart concentrated on a description of the environment which the aircraft presented to the equipment to be cooled, and Mr. Welch concentrated on the problems of instrument cooling.

In his paper entitled "Problem of Cooling Electronic Equipment in High-Performance Aircraft," Mr. Carhart first discussed the aircraft environment by describing the pressure-temperature relationships for the existing environment and extended this type of environment to future operations involving aircraft with maximum speed at Mach 3 and maximum altitudes of 70,000 ft. He discussed several types of cooling system including ram cooling, single-stage air cycle refrigeration, expendable liquid cooling, and two-stage refrigeration systems. He indicated on a Mach Number-altitude scale where each of these types of cooling would be applicable for equipment with several different surface temperature limitations.

Mr. Welch's paper was entitled "Cooling Procedures Necessary to Avionic Reliability." First, he discussed the details of the mechanism of heat transfer within various avionic heat sources such as vacuum tubes, resistors, transformers, inductors, transistors, etc. He then discussed the natural heat flow paths and compared the methods of cooling electronic equipment such as natural cooling, free convection radiation, forced air cooling, direct liquid cooling, and vaporization cooling. Mr. Welch described experiments to measure the heating problems associated with some avionic components and then discussed the possibilities of requiring constant temperature environment for certain of these components, such as transistorized equipment. He described a special technique in thermoelectric cooling, showing an example of a Peltier cooling thermopile which produced a temperature drop of 16°C. with an apparent efficiency of 17 per cent at 1.2 watts, indicating a possible use for cooling transistors. The audience response in questions and discussion on these two papers on the problem of cooling electronic equipment was great; unfortunately, time did not permit it to be carried to its finality.

The third paper was titled "The Impact of Electronic Equipment on Electric Generator Design and Aircraft Power Plants." It was written by Henry Rempt and M. J. Cronin of the Lockheed Aircraft Corporation and was presented by Mr. Rempt. The growth in man-hours, cost, and weight of the electronic system in typical aircraft was shown for the period 1940–1955. During this time, the electronic system has grown from 2½ to more than 10 per cent by weight, from 16 to more than 48 per cent in cost, and from 11½ to 38 per cent in man-hours. With this great growth in the importance of the electronic system in aircraft, Mr. Rempt illustrated some of the details of equipment design, location, and performance in the aircraft; he particularly concentrated on the problems associated with turbojet and turboprop aircraft. Messrs. Cronin and Rempt's paper, punctuated with a good deal of the type of humor which experience generates, was well received by the audience.

The final paper of the session on electronics was written by R. J. Henderson, and G. P. Allison of The Glenn L. Martin Company. It was entitled "Aircraft Electronic Equipment, Contoured Versus Standard" and was presented by Mr. Henderson. In this paper were highlighted some of the problems which the aircraft designer faces in the installation of electronic equipment for high-performance aircraft. The relative balance was discussed between the cost of extensive electronic system repackaging to fit a particular aircraft versus the penalty in reliability and other performance parameters involved when repackaging is done. The authors suggested that, since the shape of aircraft during the next decade was known approximately, a practical set of standard packaging shapes for electronic equipment could be established to permit more flexibility in the installation. They suggested an approach in the standardization of extremely small elements of equipment—to be assembled in larger

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tailored packages for particular installations. Admittedly, this paper was somewhat of a first cut at this problem of standardization, and it accordingly generated lively discussion and some measure of disagreement. All concerned, however, agreed that anything that could be done to improve this situation would be of great help.

Engineering Management Philosophies

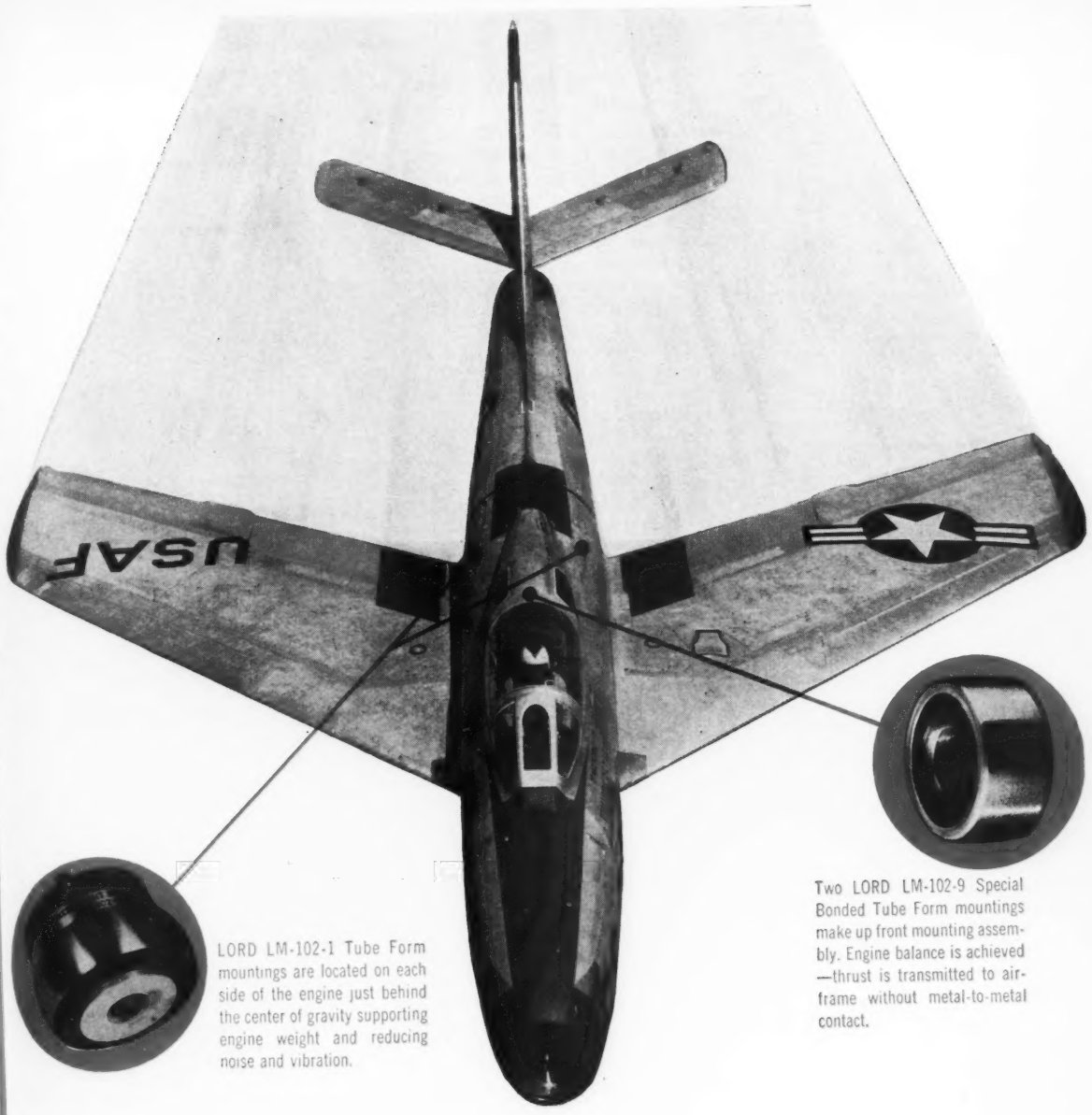
by
Edward A. Ledeen
Engineering Administration
Wright Aeronautical Div.
Curtiss-Wright Corp.

A topic new to the agenda of the Annual Meeting, engineering management philosophies, was presented as an open-forum panel discussion at the afternoon meeting on January 23. The meeting was opened with the reading of four short papers by the members of the panel: Clarence Linder, Vice-President—Engineering, General Electric Company; Robert Furhman, Chief, Technical Section, Ryan Aeronautical Company (substituting for Frank Fink); Willis Hawkins, Director of Engineering, Missile Systems Division, Lockheed Aircraft Corporation; and George Trimble, Vice-President—Engineering, The Glenn L. Martin Company.

Mr. Linder's paper, "The Engineer's Share in Success," discoursed upon the interrelationship of engineers and management, proper communication between the two, and the responsibility of management to provide recognition, means of self-development, and integration of engineering personnel with other aspects of the entire corporate structure to create a harmonious foundation for progress.

Mr. Trimble presented "A Guiding Principle for Engineering Management," a discussion covering the need for individualistic "liberty" in the form of freedom of action in the fields of research and development, coupled with a balance of "justice" in the form of guidance and supervision.

Mr. Furhman delivered a paper on "Engineering Management Philosophies toward the Engineering Shortage" that had been prepared by Frank Fink, Vice-President and Chief Engineer of Ryan Aeronautical Company. The use of nonengineering personnel, analog and digital computers, and other engineering tools and aids was presented as a



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means toward implementing the engineering staff. Assistance to educators and elimination of duplication of effort inside and outside the plant were other approaches discussed to achieve the same goal.

Speaking on "New Responsibilities of Science and Engineering in Weapon System Development," Mr. Hawkins outlined the technical and scientific functions which must now be performed in creating new weapon systems. He touched briefly upon the contributions required from scientists, designers, and project managers to achieve the teamwork required in present-day weapons systems development.

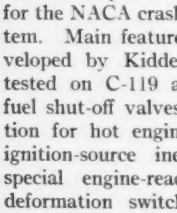
Following the presentation of the four prepared papers, the meeting was opened for discussion from the audience. A lively participation resulted with comments from many of the 262 persons present. Among the contributors to the discussion were W. K. Ebel, Canadair, Ltd.; J. H. Sidebottom, Flight Refueling, Inc.; Ernest G. Stout, Ralph M. Parsons Company, Inc.; Scott Hall, British Ministry of Supply; Joel Jacobson, Aircraft Armaments, Inc.; and B. R. Teree, The Weatherhead Company.

Flight Safety and Training

by
Jerome Lederer

Director
Flight Safety Foundation, Inc.
and Cornell-Guggenheim Aviation Safety Center

Held in cooperation with The Daniel and Florence Guggenheim Aviation Safety Center at Cornell University, the session on flight safety and training featured three papers:



"Crash Fire Prevention — Research to Flight Test," presented by I. J. Hammill with E. R. Zeek, both of Walter Kidde & Company, Inc., detailed the design and development of the mechanisms for the NACA crash fire prevention system. Main features of the system developed by Kidde soon to be flight tested on C-119 aircraft include new fuel shut-off valves, a coolant installation for hot engine-exhaust parts, an ignition-source inerting system, and special engine-reaction and aircraft-deformation switches to actuate the crash fire prevention system only when the aircraft is in contact with the ground. With some modification, Mr. Hammill reported, this system is applicable to jet aircraft.

In conjunction with this discussion, a color film was shown of the original NACA C-82 crash-tests to determine the sources of ignition in a survivable type of crash.

"Helicopter Flight Trainer," presented by Adm. Luis de Florez of The de Florez Company, Inc., detailed the studies and methods employed to arrive at a practical training device to aid conversion of fixed-wing pilots to helicopter techniques. Admiral de Florez pointed out that hovering had proved to be the most difficult maneuver for a pilot to master. An analysis of this problem indicated that visual simulation was a primary requirement, with kinesthetic clues (roll, pitch, vertical accelerations, etc.) of little importance. Further research showed an adequate illusion of motion could be created by a light "point source" projection technique. A working model proved that an illusion of flight could be created synthetically by this simple projection which would be adequate for hovering training.

A prototype device, designed and built as a result of The de Florez Company study, is being installed at NAS, Pensacola, Fla., for evaluation.

"Safety and Economic Aspects of Flight Simulators," was the paper presented by Allen F. Bonnalie of United Air Lines, Inc. In discussing the use of electronic mechanical flight simulators in air-line training programs, Mr. Bonnalie reported that his company had found the simulators to be the finest tool available for (1) training new crew members, (2) conditioning crews for new aircraft, (3) upgrading copilots, (4) disclosing possible need for better cockpit organization, and (5) proficiency training of both flight and ground crews. United's preference, he stated, is for "whole task" simulators rather than "part task." The Convair 340 and DC-6 simulators are in operation 23 hours a day, 7 days a week. Maintenance is performed by factory-trained electronic technicians and includes progressive overhaul plus periodic test flying with the airplane to ensure verity of simulation.

Use of simulators for training, Mr. Bonnalie explained, releases line aircraft for revenue-producing flights instead of tieing them up on training missions. Economically, therefore, the use of simulators offers all air lines a dollar advantage, as well as a flight-safety advantage. United estimates that the use of simulators in its 1956 training program will provide a total net gain of $2,171,800, accruing from both training-cost savings and the earning potential of plane hours saved by the use of simulators rather than actual line aircraft. The company expects to have a DC-8 flight simulator in operation a full year before the first DC-8 training plane goes into operation.

Mr. Lederer closed the interesting discussion with a short NACA color film on "Crash Loads" which showed the "*G*-forces" encountered by occupants of aircraft in crashes.

Guided Missiles

by
Brig. Gen. Marvin C. Demler, USAF

Assistant Deputy Commander
Research and Development
Headquarters, ARDC

For this session, the speakers attempted to consolidate unclassified information into interesting and instructive packages. The Air Research and Development Command of the United States Air Force appreciates the mutual benefits derived from exchanging information with the scientific community and desires to encourage this activity within the framework of security regulations.

All of us, as citizens of the United States, face the stark facts that the current international situation requires our maintenance of superior military air power; the U.S.S.R. has placed great emphasis on science and basic research to develop advanced air weapons; qualitative superiority of United States air power requires accelerated effort by American science and industry; our scientific and aeronautical engineering training programs must be enlarged; we must, within the framework of a free economy, encourage more efficient use of the engineering and scientific manpower now on hand; and, like the Soviets, we must stimulate the desire for scientific careers in our youth. We must, in the words of Lt. Gen. Thomas S. Power, Commander of the ARDC, "create the picture of a 'Davy Crockett' of science, the modern pioneer fighting on the frontiers of human knowledge."

Today's guided missile is a far cry from the Sperry-Kettering pilotless aircraft of 1918. The guided-missile era did not begin in earnest until the introduction of the V-1 and V-2 by the Germans in 1944. Had these been equipped with nuclear warheads, the outcome of World War II might well have been decided in favor of the Germans. In the ensuing years, the United States has expended much effort in catching up with—and overtaking—German technology. We certainly will not have a "second chance" in the future. Our effort is aimed at qualitative, rather

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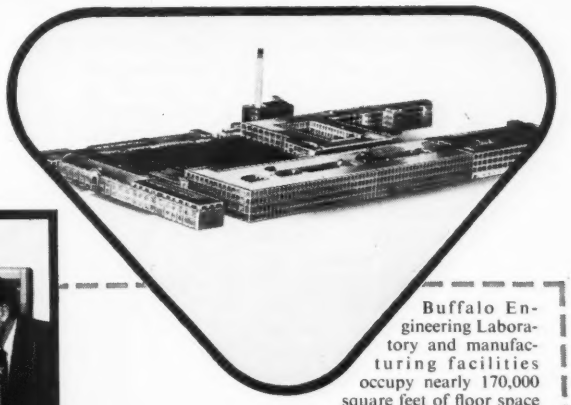
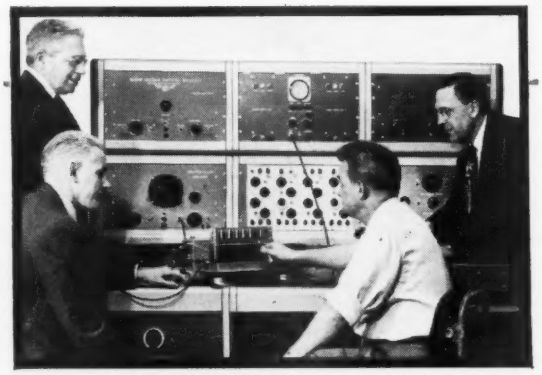


Buffalo Engineering Laboratory and manufacturing facilities occupy nearly 170,000 square feet of floor space in this industrial center at 175 Great Arrow Ave., Buffalo 7, New York.



Observing measurement of circuit parameters in the Electronic Systems Division's Buffalo Engineering Laboratory. From left: *H. C. Tittle*, Manager—Buffalo Operations; *M. C. Scott*, Manager—Buffalo Engineering Laboratory; *R. W. Ferry*, Assistant Product Engineering Manager and *A. W. Puttick*, Product Engineering Manager.

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In all of Sylvania's Electronic Systems Division installations, the right people work with the right facilities, within a sound managerial environment. That is why they have produced the right solutions to a variety of problems, and have made such important contributions in the fields of aviation electronics, guided missiles, countermeasures, communications, radar, computers and control systems. Whether the problem is military or industrial, Sylvania's business is to come up with electronic solutions that are *producible*.

In addition to its Buffalo Engineering Laboratory and manufacturing facilities, the Electronic Systems Division has installations at Waltham, Mass., and Mountain View, Calif., staffed with top-ranking scientists and engineers, and backed by Sylvania's extensive resources in the electronics field.

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than quantitative, objectives and, therefore, is directly dependent upon a dynamic research and development program.

The advent of the guided missiles will complement manned aircraft much as field artillery has complemented hand-carried weapons in the past. Missiles will not supplant manned aircraft in the Air Force arsenal in the foreseeable future. Present plans call for the use of air-to-air missiles to increase the kill probability of manned aircraft, tactical missiles to supplement the abilities of our tactical bombers, ground-launched interceptor missiles to protect our own resources from attack, air-to-surface missiles for our strategic bombers, and intercontinental missiles to supplement the power of the Strategic Air Command.

Guidance and propulsion are two areas where considerable technical effort has been applied because of the unique requirements of missiles. Guidance systems generally differ, depending upon whether flight paths can be preprogrammed against fixed targets or must be established to collide with maneuvering targets. Those systems which can be preprogramed may use celestial or inertial navigation principles, as well as radio or radar techniques. Guidance against maneuvering targets demands continuous information on the line of sight and angular rate of the line of sight. Such information can be obtained only by equipment which continually "sees" the target. Your Air Force, through industry and educational institutions, is achieving a considerable degree of success in making the step from the rudimentary guidance systems developed in Germany more than a decade ago to the systems which are under development today and which will make each missile count.

Ram-jets and rockets, both solid and liquid, are finding extensive application in guided missiles. The principal reason for this is the inherent reliability of these types of power plants for one-shot applications. The solid rocket, of course, represents the ultimate in simplicity and reliability in aircraft propulsion. Its development problems are associated with obtaining high performance and reducing the cost of solid fuel. The liquid rocket finds application where compactness is of primary importance. Reliability considerations have greatly influenced the mode of developing these liquid rockets. Ram-jet development has proved the feasibility of this type of power plant. It finds application where high speed, high altitude, and longer range are important. On the basis of current knowledge, we can assign each type of power plant to a specific role in the guided-missile arsenal.

Articles have appeared recently which indicate that the ultimate goal of top military planners is the intercontinental ballistic missile. This is but a means of gaining time—time to be used by our Government to assert its influence in world affairs for the establishment of a permanent and lasting peace based on the dignity of the individual human being. Truly, this is the ultimate goal of all of us.

Helicopter Dynamics

Alexander H. Flax, Chairman

Assistant Director
Cornell Aeronautical Laboratory, Inc.

This session, cosponsored by the American Helicopter Society, offered four papers. George W. Brooks, of NACA's Langley Aeronautical Laboratory, presented the first one, "Analytical Determination of the Natural Coupled Frequencies of Tandem Helicopters." His analysis included the following degrees of freedom: fuselage translation, pitching, and bending; rotor blade translation, flapping, and bending; and engine translation. Sample calculations for a typical helicopter were presented to show the effects of significant parameters, as well as the agreement between the calculated and measured coupled frequencies.

R. H. Miller, of Massachusetts Institute of Technology, and C. W. Ellis, of Kaman Aircraft Corporation, collaborated on a study of "Helicopter Blade Vibration and Flutter." The effects of steady elastic flapwise and lagwise bending deflections were investigated and the influence of the first elastic flapwise bending mode considered. It was shown that the blade instabilities, either flutter (oscillatory) or divergence (instability), may occur even if the blade c.g. is ahead of the aerodynamic center and elastic axis. It was further shown that periodic shear transmitted to the hub and periodic bending moments in the blade may be appreciably reduced by a proper combination of blade mass balance and torsional natural frequency.

Abner Rasumoff, of the Aircraft Division, Hughes Tool Company, delivered a paper on "Minimization of Rotor Blade Cyclic Stresses by Variation of Spanwise and Chordwise Mass Distribution." Spanwise mass distribution was shown to affect primarily blade beamwise natural frequency and to be important for control of blade resonance effects. The primary effect of chordwise mass distribution is to produce a twisting of the blade as a result of a coupling with blade flapping and bending motion, and thereby to produce a cyclic airload that appears to have the effect of damping the cyclic bending motion. Discussing substantiating model and flight tests of the XH-17 helicopter, the author said that, in the case of the XH-17 rotor blade, blade cyclic stresses were reduced 35 to 45 per cent in all flight regimes tested. This was accomplished by adding a concentrated mass, equivalent to 6 per cent of the blade weight, to the blade leading edge near the first mode nodal point.

The last paper presented the joint work of Hamilton Daughaday and Frank Du Waldt, of Cornell Aeronautical Laboratory, Inc. It was titled "The Effect of Blade Root Properties on the Natural Mode Shapes, Bending Moments, and Shears of a Model Helicopter Rotor Blade." Recent data for articulated rotor blades have called attention to the existence of considerably higher vibratory bending moments than were generally expected in the region of the blade root and attachment fitting. The authors showed that the first mode bending moment distribution and the corresponding vibratory forces transmitted to the fuselage are much influenced by the moment of inertia of the root flapping fitting and to a comparatively small extent by root bending stiffness. High root moment peaks and large fuselage exciting forces are found when the root inertia is large.

Helicopter Test and Development

by
Nicholas M. Stefano

Chief, Rotary Wing Section
Fairchild Engine and Airplane Corp.

The first paper of the session was presented by the author, John E. Yeates, Jr., Research Scientist, Langley Aeronautical Laboratory, NACA. The title was "A Discussion of Helicopter Vibration Studies Including Flight-Test and Analysis Methods Used to Determine the Coupled Response of a Tandem Type." The importance of this paper arises from the fact that it presents test results of the first application to helicopters of two important vibration engineering techniques—namely (1) forcibly vibrating a structure in flight to determine the response of the complete dynamic system and (2) analysis of the test results by power

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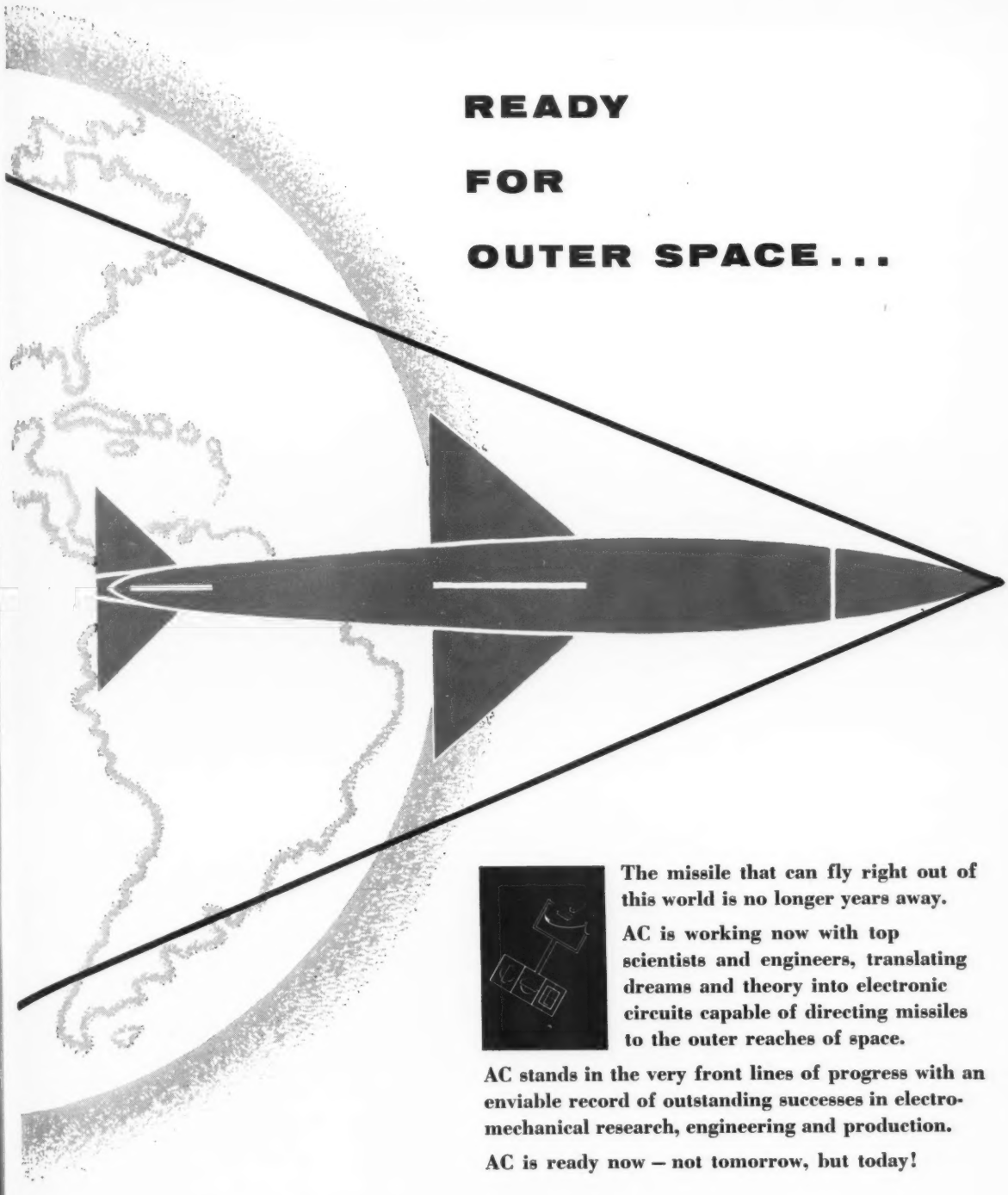

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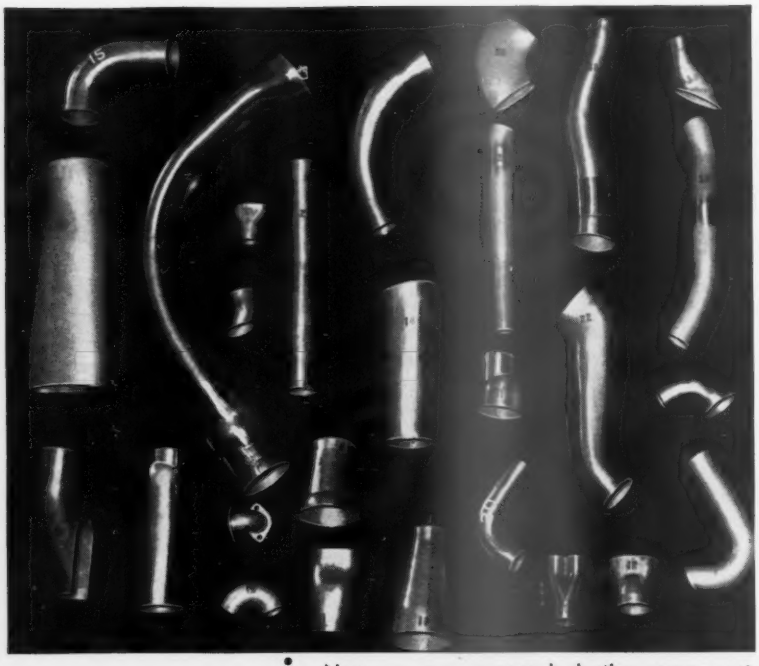

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spectral density analysis (or generalized harmonic analysis) using magnetic tape recording equipment and a continuously scanning band pass filter device, called a power spectral density analyzer, developed by the NACA.*

As shown in a paper presented in the helicopter dynamics session ("Analytical Determination of the Natural Coupled Frequencies of Tandem Helicopters," by George W. Brooks), the vertical vibratory motion of a helicopter, in the vicinity of the cockpit, results from modes involving a considerable amount of blade motion. Since the blade stiffness is a function of rotor speed, it was discovered that the vibration characteristics of the helicopter could not be adequately established by ground testing. Accordingly, a technique was devised for establishing these characteristics in flight. Since the ship appeared to be responding principally to a 3 per rev rotor loading, a shaker was mounted on the front rotor gear box to excite vertical motion and was designed to traverse a frequency band from 8 to 17 cycles per sec. over a period of 1 min. The oscillograph record showed that an ordinary Fourier analysis is not possible because the records did not repeat in cyclic fashion. This does not present any problem if the power spectral density analysis is used. The oscillograph data is transferred to magnetic tape, a closed loop of tape is used from that part of the record of interest, and the tape is run on the electrical equipment to give a plot of power spectral density versus frequency. The fundamental equation for measuring the response is then given by

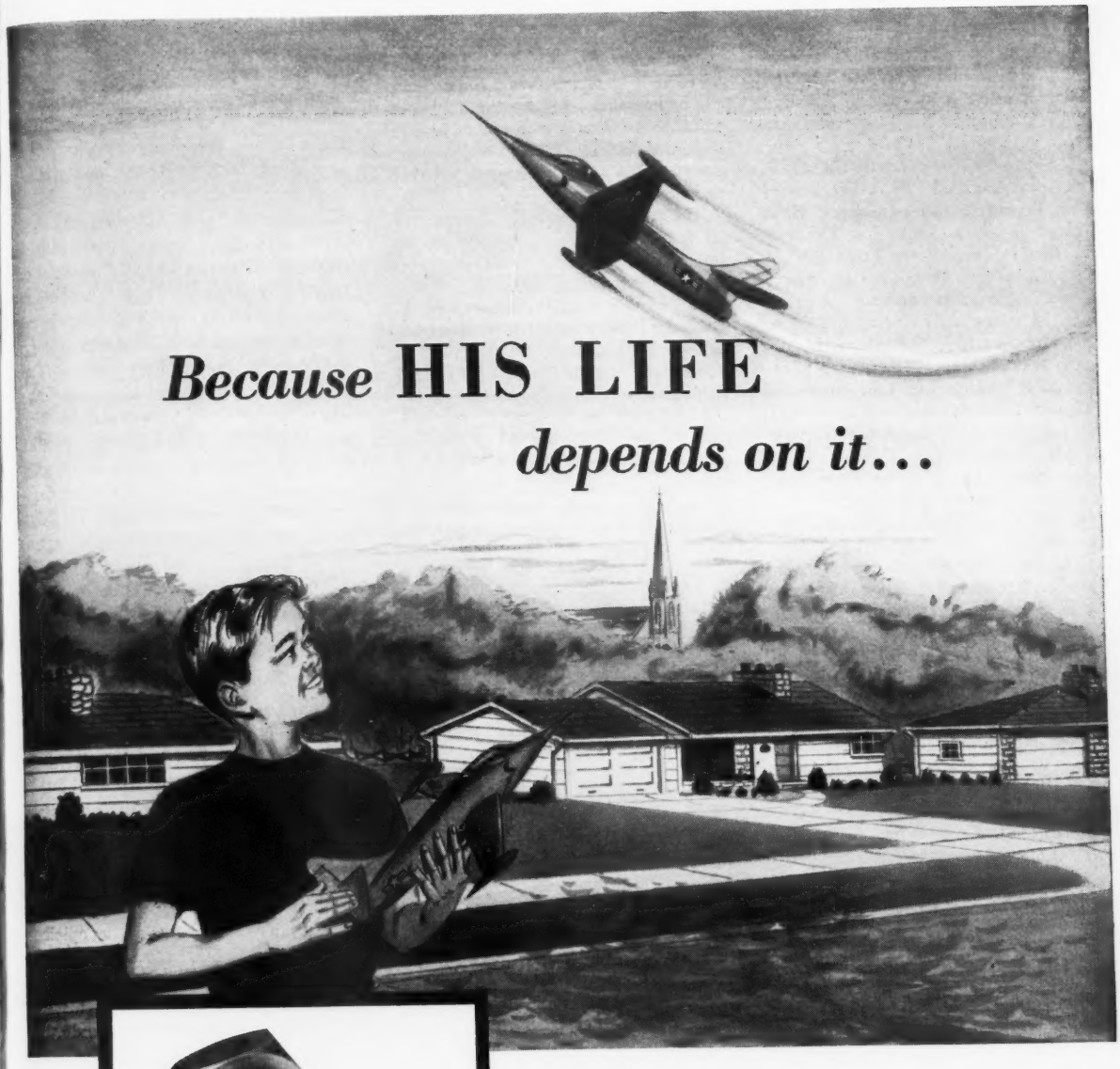
$$\text{Response} = \frac{\text{Output (due to shaker)}}{\text{Shaker Input}} = \frac{\text{Total Output} - \text{Natural Output}}{\text{Shaker Input}}$$

where the variables noted are obtained from a power spectral density analysis of each item. A plot of Response vs. Frequency is then made, revealing the fundamental vibration characteristics of the ship.

In the case investigated, it became apparent that a small change in rotor speed resulted in a marked variation in the characteristics of the dynamic system, further emphasizing the value of this "in-flight" testing technique.

Mr. Yeates suggested several improvements in the techniques which are worth a study of the paper and its refer-

* This device, and associated equipment, was described in the paper, "Analog Equipment for Processing Randomly Fluctuating Data," by Francis B. Smith, AERONAUTICAL ENGINEERING REVIEW, May, 1955, pp. 113–119.



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ences by those whose field of interest is helicopter vibration engineering. The application possibilities of "probability distribution," "power spectral density," and "cross spectral density" in helicopter vibration work seem limitless.

The second paper, given by Charles F. Rice, was entitled "Investigation of Whirl Test Methods for Inducing Flight Fatigue Loads in Helicopter Rotors." Mr. Rice is Chief of the Rotor Project and Test Section, Propeller Laboratory, Wright Air Development Center, Wright-Patterson AFB, Dayton, Ohio. He pointed out that the extended whirl test is the ". . .accepted approach to establishing bearing life, lubrication requirements, substantiation of most rotor hub components; determining overhaul periods; and checking a multitude of detail design items under reasonably simulated operating conditions."

Mr. Rice then explained that, despite this situation, the most severe flight fatigue conditions are not reproduced in the whirl test and that bench-type tests are used to overcome this defect, but the inevitable compromises in attempting to simulate the actual loading leave much to be desired. Oscillation of the swash plate at several times rotor speed and use of a propeller slipstream directed tangentially into the rotor disc appear to offer a solution to the problem. However, the swash plate oscillation method imposes excessive loads upon the control system on both teetering and articulated rotor systems, and, in the case of teetering rotors, rotor shaft bending stress levels also are too severe. The propeller slipstream method is satisfactory for both types of rotor. However, for large rotors the propeller installation and operation itself may be a limiting factor. Further development is due in this field.

The author concluded that whirl test excitation methods are useful test procedures but must tentatively be considered as supplementary to the "non-excited" endurance whirl tests and bench tests since many component failures are discovered in these tests at "moderate" loads.

This reporter would like to hasten the day when an "excited" whirl test will be used to substantiate all the rotor components. This paper represents a vital contribution in that direction.

R. H. David, Power Plant Design Specialist, Hiller Helicopters, presented the third paper, "Design and Flight Test Development of McCulloch VS-57 Supercharger Installation on Hiller Model UH-12B Helicopter." R. W. Cowgill, Chief Flight Test Engineer, and R. D. Collins, Flight Test Engineer, both of Hiller Helicopters, were joint authors with Mr. David.

Within the last few years, helicopter users have demanded increasingly better vertical take-off ability at high altitudes and high temperatures. Supercharging or larger engines are the only solutions, aside from a rather complete redesign of the rotor system which would compromise other helicopter characteristics.

The solution chosen in this case was an external supercharger, driven by the tail rotor drive system. The reasons for this choice, as given by Mr. David, were "low cost of components, low development costs, relatively short development time, retrofit possible for helicopters already in operation, and immediately available components."

Difficulties had been expected in adapting the McCulloch VS-57 automative supercharger in the following areas: (1) engine cooling, (2) engine detonation, (3) carburetor action due to pressurization, and (4) structural limitations of the tail rotor drive.

Engine cooling and detonation tests established that there were no problems in those areas. Carburetor problems were solved by use of a pressure and temperature compensating carburetor (Marvel MA4-5AA). The structural limitations were resolved. The main difficulties were associated with the supercharger drive and controls. Selection of a single operational speed for the supercharger and redesign of a pulley drive system and clutch between the tail rotor drive and impeller solved the drive problem but introduced induction system airflow and pressure problems. These problems were solved by a throttle valve on the supercharger outlet and an air dump valve between the throttle valve and the carburetor, the air dump valve being linked to the carburetor throttle to dump air when the demand for air was low.

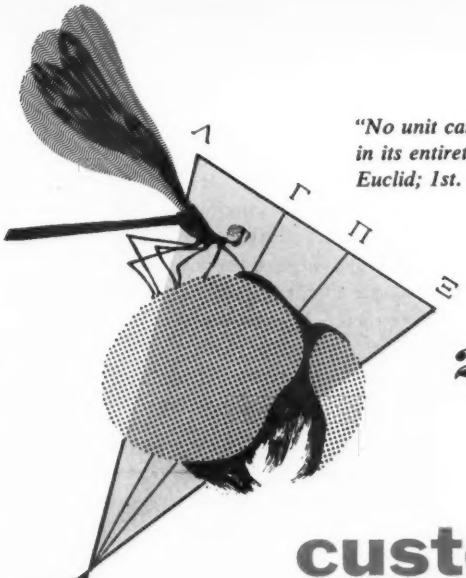
The net result is a relatively economical installation which raises the hovering ceiling (out of ground effect) of the helicopter from 3,200 to 8,100 ft. The presentation was candid and to the point, and the information is particularly timely.

The fourth paper was entitled "Experimental Study of a Tandem Helicopter Employing Cocked Vertical Blade Hinges." It was presented by the author, Peter F. Leone, Chief Vibrations Engineer of the Kellett Aircraft Corporation. This experimental study was "...motivated by the quest for a device which would eliminate the rotor ground instability at high partial air-borne conditions experienced by a conventional helicopter employing low offset, uncocked vertical blade hinges and air-oil shock struts in its landing gear." The device selected was a blade lag hinge the vertical axis of which is canted at the top, in the direction of rotor rotation. The cant angle (or α_2 angle), as measured from the vertical, is 45°. It was found that the effective damping constant could be halved, without danger of "ground resonance," from zero rotor lift to take-off; whereas, with full damping and zero α_2 angle, "ground resonance" could be excited at 60 to 82 per cent of take-off collective pitch, depending upon rotor speed. An important point is that the original lag hinge design included a lag hinge spring. The value of this was halved also in the case where $\alpha_2 = 45°$. However, it was established that the kinematic effect of the spring and the α_2 angle of 45° was a coupling between the rotor blade flapping and lag motions, and the dynamic effect was an increase in the natural frequency of that mode primarily involving lag motion. There was no change in the frequency of the mode primarily involving flapping.

The test results, when plotted, showed many effects of the cocking of the vertical hinge. Most effects were slight and, apparently, not readily predictable. However, the critical flight blade bending moments in the flapping direction and lag direction were affected both favorably and unfavorably, leading to the conclusion that indiscriminate use of cocked vertical hinges is not recommended. There is a possibility, however, in the opinion of the reporter, that this research may lead eventually to the elimination of lag hinges in articulated rotor blades. The author and his firm, and the sponsors—the U.S. Army and the Bureau of Aeronautics—are to be commended for making this research public knowledge so quickly after the results were established.

Historical Activities Meeting

Several early airmail pilots joined in this discussion, reminiscing on their experiences in flying the mail in open-cockpit biplanes. The panel speakers were Walter Braznell and Si Bittner of American Airlines, Inc.; W. D. Williams of United Air Lines, Inc.; H. T. (Dick) Merrill of Eastern Air Lines, Inc.; Frank E. Niswander of Trans World Airlines, Inc.; and Charles I. Stanton of Bell Telephone Laboratories. The Moderator was Ernest A. Cutrell of American Airlines.



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Hypersonics

by
Arthur Kantrowitz

Professor, Graduate School of Aeronautical Engineering Cornell University

The hypersonics session at the Institute meetings this year reflects the growing interest in very-high-speed flight. The four papers presented covered some of the most significant problems in this relatively new field. The first two presentations were theoretical analyses of the inviscid flow in the "shock layer"—i.e., between the body surface and the bow shock. To round out the program, the third and fourth papers presented experimental results on viscous and thermal effects at high Mach Numbers.

In the first paper, Prof. Ting-Yi Li of Rensselaer Polytechnic Institute and Richard Geiger of General Electric Company discussed the inviscid stagnation point flow on a blunt body of revolution moving at hypersonic speeds. The paper was presented by Mr. Geiger. Solutions were obtained by solving the momentum and continuity equations with the use of hypersonic simplifications in the incompressible flow region near the stagnation point. Solutions for two-dimensional and axially symmetric bodies were presented, giving the shock separation distance, velocity distributions, and surface pressures near the stagnation point. The results were shown to agree with recent investigations of Lees and Hayes, and comparison with available experimental information was made. Unfortunately, most of the experimental results do not yet extend to flow velocities high enough to satisfy clearly the hypersonic flow assumptions. The method is applicable to dissociated gases, provided the incompressibility assumption is not violated.

The next presentation, by Prof. Wallace D. Hayes of Princeton University and consultant to the Ramo-Wooldridge Corporation, considered the inviscid hypersonic flow problem for regions farther away from the stagnation point. Using hypersonic flow assumptions, as well as the assumption of constant stream tube area, Professor Hayes gave approximate solutions for a body of revolution. Considerable discussion was prompted by the fact that, at a certain critical shock angle, singularities appeared in the solutions. The speaker pointed out that these solutions with singularities are analogous to the solutions for incompressible flow under gravity. Eggers remarked that in work currently being done at the NACA Ames Laboratory it has appeared that the exact shape and position of the sonic line has a strong effect on the solutions, which did not appear to be the case in Hayes's method. An improved analysis relaxing the constant stream tube assumption and an iterative scheme for using the method were suggested by the speaker.

The next paper was a report of a careful experimental investigation on leading-edge shock wave—boundary-layer interaction in the GALCIT 5 by 5 Mach 5.8 wind tunnel. Presentation was made by James J. Kendall, Jr., Research Associate at the California Institute of Technology. Care was taken to obtain a sharp leading edge and thus minimize the leading-edge effect on the induced pressure. This makes these results particularly significant for comparison with the interaction theory. Measurements of induced pressures were made by orifices on the plate surface, and profiles of flow variables were calculated from impact pressure surveys at various distances downstream of the leading edge. It was pointed out that the weak interaction theory predicts induced pressures somewhat lower than the measured values. In addition, the total drag is higher than the zero pressure gradient value near the leading edge but approaches that value downstream.

In the final paper, Eva M. Winkler presented the results of heat transfer and pressure measurements in the Mach Number range 5–8 made at the NOL Hypersonic Wind Tunnel. J. E. Danberg of NOL was coauthor of this paper. Various wall to free-stream temperatures were used, and the Reynolds Number range, based on model diameter, was 10^5 to 10^6. The models were hemisphere cylinders instrumented with pressure orifices and surface thermocouples. A tendency for the measurements to show slightly higher than expected heat-transfer rates at about 11° and 40° from the free-stream direction was noted by the author. This evoked considerable discussion, though the experimental evidence is not conclusive.

Instruments

by
Charles F. Savage

Consultant, Professional Relations Engineering Personnel Department General Electric Company

This program was characterized by two frames of reference—the large number of highly qualified authors of the papers and the large number of persons who attended the meeting evidencing the high level of interest in instruments and instrumentation as an important factor in the progress of aviation.

While the program listed four papers by title, there were actually five with some subject interrelation.

The first two papers, "The Precision Servo-Type Thermocouple Temperature Indicating System" by George H. Cole, Design Engineer, Minneapolis-Honeywell Regulator Company, and "Dynamic Consideration Relating to the Inertial Space-Stabilized Platforms" by Edward Gorszycki of the Sperry Gyroscope Company Division, Sperry Rand Corporation, had for their subject matter instrument systems which were not related to each other. The first, covering the temperature indicating system, described a rather specific instrumentation revolving about the high-performance needs of jet engines. The general principles of the servo-type indicating system as actuated by thermocouples were described in some detail. The boundary conditions of operation in terms of accuracy, precision, speed of response, weight limitations, and other factors were also described. Since the descriptions were very specific, discussions centered around the types of thermocouple, speed of response, and presentation to the pilot.

In contrast, the second paper was in the nature of a review of general principles to give those in the audience not familiar with space-stabilized platforms a better understanding of their operation, function, performance, and purpose. This was done with the aid of diagrams and slides. The actual paper covered in mathematics the principles of operation described by Mr. Gorszycki. Because the terminology was unfamiliar to some, discussion centered about the orientation of the platform with respect to space and any reference thereto with any vertical or earthbound orientation.

The next two papers on the program illustrated the manner in which products

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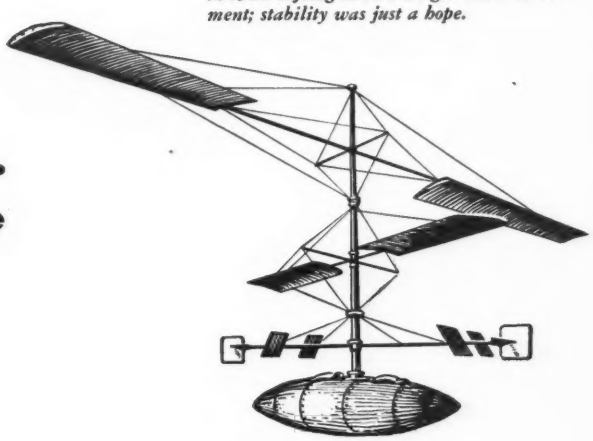

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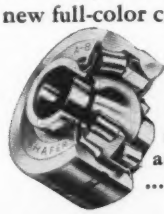

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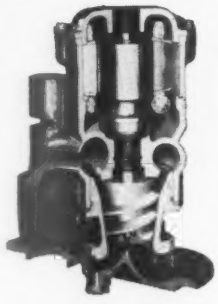

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or principles having common operational aspects can complement each other. Clarence A. Haskell's paper, "Mass Flowmeter Summation System," described a system which measures and indicates the total fuel-flow rate to all engines in multiengined aircraft and, in addition, indicates the fuel-flow rate to each engine. The system provides a summation for two to eight engines and is completely automatic, requiring no calibration or adjustment in the aircraft. Knowledge of the rate of fuel consumption permits a running evaluation of engine performance and the computation of remaining flight time. It was this presentation on measurement or the computation of remaining flight time that tied this paper with those that followed. In addition, the summation system provided an output signal proportional to total flow rate for aircraft control functions, recorders, or flow rate integration. The system described measures true mass fuel-flow rate by utilization of a momentum principle and is therefore independent of the fuel density. Again, and because this was essentially a paper describing a product as well as a principle, it was possible to illustrate the flowmeter by means of attractive color slides. Discussion centered on the unique parallel-series transformer summation scheme and on the principles of operation of the flowmeter itself. Adequate reference material, as well as presentations on similar types of mass flowmeter, led to discussion of adopting this particular technique to more extensive use of flowmeters. Association with an outstanding expert in the field of flowmeters, Dr. Y. T. Li, was extremely helpful to the overall presentation of this paper.

The highlight of the instrumentation program was the reading of the two following papers on the integrated subject of cruise control for turbojet aircraft. "Programed Cruise Control," written by Dr. Y. T. Li, A. J. Navoy, and Dr. Myron A. Hoffman, was presented by Dr. Hoffman. The primary purpose of cruise control presentation for aircraft is to enable a pilot to obtain a maximum possible range. In order to accomplish this, the pilot must be provided with an accurate indication of the optimum cruise altitude and Mach Number, an effective technique for maintaining the aircraft in these conditions. The paper as presented first examined the basic cruise characteristics of turbojet aircraft and then briefly evaluated the present cruise control aids. A relatively simple instrumentation scheme based on certain so-called "invariant cruise parameters" was described. The invariant parameter cruise technique required accurate performance data for the particular type of aircraft. This is inherently a program technique which takes advan-

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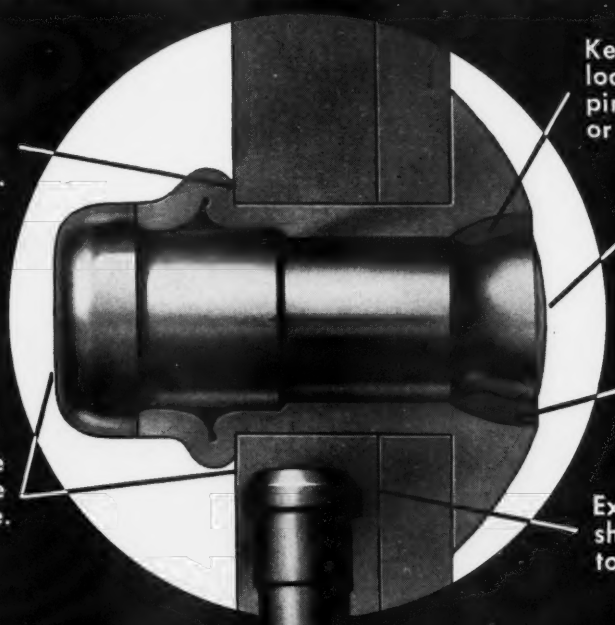
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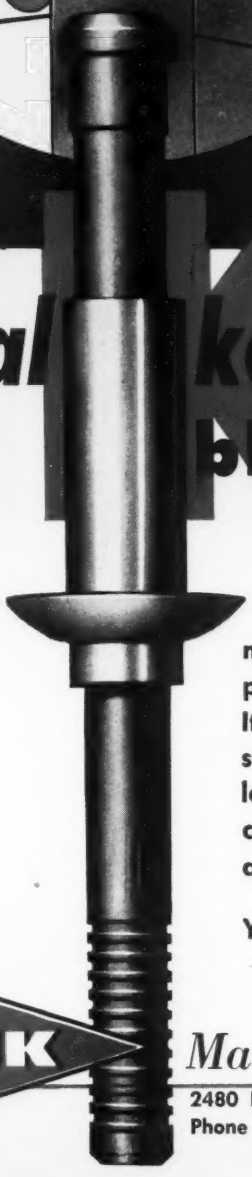

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tage of certain unique characteristics of high-speed aircraft cruise. The accuracy requirements, transient flight considerations, and data presentation problems were discussed, with emphasis on providing simple cruise control instrumentation to meet the immediately pressing needs of the current turbojet aircraft. Division of the concept of aircraft performance and limitations into three cruise categories—thrust-limited, Mach-limited, and a combination of thrust and Mach-limited—appealed to the audience and occasioned much discussion. Discussion also developed the fact that complicated high speeds of flight and the changing parameters of the cruise made it practically impossible for the human element to do the necessary calculations so that a program of cruise control became almost a necessity. The work on this M.I.T. cruise control project was under Air Force sponsorship and the emphasis primarily on military problems and successful completion of various important classes of missions. However, the general cruise control principles developed should prove of value to the commercial operation as well.

The final paper, which was coordinated with the program cruise control paper and also fit very well with the flowmeter paper, was entitled "Optimalizing Cruise Control for Turbojet Aircraft." It was written by Dr. Y. T. Li, Anthony J. Navoy, and Dr. William B. Bryant, all of M.I.T., and was presented by Dr. Bryant. Based on the knowledge obtained from the previous paper, it was easy to follow the description of the cruise control problem of the long-range turbojet aircraft. This is synonymous with the problem of adjusting air speed and altitude to maximize the instantaneous specific range. The technique of optimalizing control provides an attractive automatic means for solving this problem without relying on previously obtained performance data. The characteristics of an optimalizing cruise control system utilizing a controller of a peak-holding type were described. The dynamic and interference effects were analyzed, and typical hunting performance curves were presented. Effective inaccuracies in the fuel-flow and air-speed measurements and a discussion of safety features were included. Various points of interest were the typical flow rates versus air-speed relationships for turbo aircraft, the sources of interference which in the case of optimalizing cruise control is atmospheric turbulence, and the inaccuracies of instrumentation. Since the optimalizing controllers are designed to indicate the deviation of the specific range from its maximum value, the absolute scale of the specific range measurement is not relatively important. There was much discussion on the hunting techniques involved and on the status of the particular investigation. The paper pointed out that the application of optimalizing cruise control to the long-range turbojet aircraft is quite feasible. The theoretical analysis as presented is to be substantiated by the construction of an experimental optimalizing controller to be tested in flight. Only in this way will it be completely possible to evaluate the usefulness of this cruise control technique.

The instrumentation session pointed the way for continued technical discussions on this important subject by linking the instrumentation with the cause and effect on the air frame, propulsion system, or navigational systems on aircraft of the future.

Internal Flow in Jet Engines

by
Abe Silverstein

Associate Director
Lewis Flight Propulsion Lab., NACA

Three papers were presented at the session on the internal flow in jet engines. The Chairman pointed out that aerodynamic problems associated with propulsion system installations have become vitally important in the development of supersonic aircraft. Among the critical problems are those of the air induction system. The inlet must be chosen to provide stable operation with high-pressure recovery and low drag while matching the engine airflow requirements over the flight range of Mach Number and altitude. In addition, the combination of inlet and subsonic diffuser must provide a sufficiently uniform velocity at the compressor face to avoid prohibitive thrust losses and stall. The first paper of the session considered the problem of obtaining high-pressure recovery and low drag. The second paper dealt with secondary flow in ducts which affects both pressure recovery and profiles.

Numerous important aerodynamic problems are also associated with the jet discharge system. The jet exit nozzle must withstand high temperatures and at the same time have variable geometry for efficient operation over the flight range. The last paper dealt largely with the effect of jet-stream interactions on the net thrust of nozzle-afterbody combinations.

Harry Drell of the Lockheed Aircraft Corporation presented the first paper, "Induction System Selection." With speeds much above Mach 2, the cowl pressure drag of conventional external compression inlets designed for high ram recovery becomes very large. He stressed the need for development of internal contraction inlets to avoid these large drag penalties.

The performance characteristics of different types of engine induction system were examined. Mr. Drell pointed out that the three-dimensional inlet has some inherent advantages in both recovery and drag over two-dimensional inlets. The results of a comparative analysis of external and internal compression inlets were then presented. Cowl pressure drags for external compression inlets were calculated assuming two-dimensional flow over the cowl contour; empirical factors were then used to correct the drags to three-dimensional values. Inlet pressure recoveries were calculated. The analysis showed the internal contraction inlet to have a potential advantage of from 20 to 50 per cent in net propulsive thrust and from 20 to 30 per cent in range. These gains were considered sufficiently large to justify the effort required to solve the difficult operational problems associated with the internal contraction inlet.

"Experimental and Analytical Investigation of Secondary Flows in Ducts" was the subject of a paper by Howard Z. Herzig and Arthur G. Hansen of the NACA Lewis Flight Propulsion Laboratory. A brief review of the three-dimensional patterns of boundary-layer secondary flows in curved ducts was presented. Experimental investigations have indicated complex boundary-layer behavior with cross-channel flows due to boundary-layer separation and vortex roll-up phenomena. The authors selected boundary-layer overturning and vortex roll-up for this investigation. Exact solutions were obtained for the three-dimensional laminar boundary-layer flows under main flows consisting of streamline translates which can be represented by means of polynomials. Streamline paths and velocity profiles within the boundary layer were computed and compared for thick and thin boundary layers with several main stream configurations. Smoke studies at low Reynolds Numbers showed that the streamlines near the walls showed good agreement with the results of the analysis.

The authors pointed out that the studies indicate a relation between vortex roll-up and the lifting of the side-wall boundary layer from the suction surface following cross flow to this surface.

The last paper of this session was "Some Aerodynamic Considerations of

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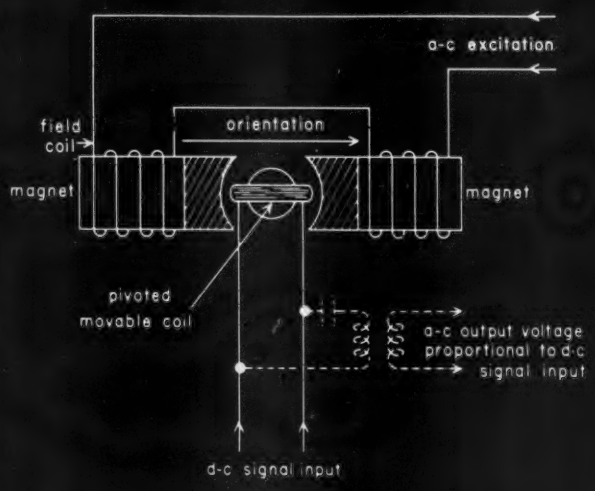

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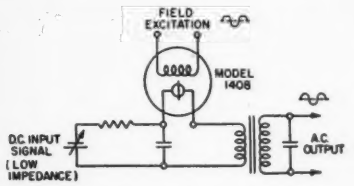

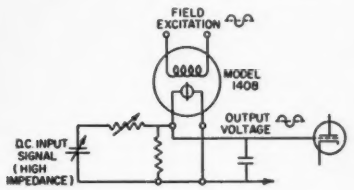

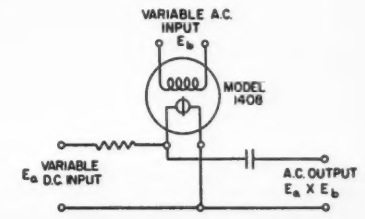

Nozzle-Afterbody Combinations" by Edgar M. Cortright of the NACA Lewis Flight Propulsion Laboratory. As flight speeds reach supersonic levels, it becomes increasingly difficult to achieve nozzle installations which are efficient over the entire speed range. Mr. Cortright pointed out that the nozzle and afterbody must be analyzed as a unit, and the complex effects of jet interaction with the external stream must be accounted for

Nozzle requirements, types, and typical installations were reviewed. Peak pressure ratios for separated turbulent boundary layers were discussed from the standpoint of predicting separation trends within nozzles during off-design operation and predicting base pressure when nozzles are surrounded by blunt bases. Characteristics of fixed convergent-divergent, ejector, and plug nozzles were described. It was pointed out that at operation below design pressure ratio the external flow can cause the nozzle flow to overexpand further than in quiescent air at the same pressure ratio. The amount of overexpansion and concomitant thrust losses depends both on the nozzle type and the installation.

Jet interference effects on boattail and base pressures were then discussed. Jet effects on boattail pressures were shown to be relatively small at supersonic speeds when the jet flow was properly expanded internally, such as with a convergent-divergent nozzle. With such nozzles, it was shown that care must be exercised to avoid blunt annular bases because of the low base pressures which result.

Meteorology

by
Arthur F. Merewether

Superintendent of Weather Services
American Airlines, Inc.
President
American Meteorological Society

The joint session with the American Meteorological Society was held Wednesday morning, January 25, in the East Ballroom before a capacity audience. Five excellent papers were given.

The first, by James K. Thompson of the Wright Air Development Center, pointed up the new problems that have developed in the exchange of information between the pilot and the weather forecaster resulting from increased aircraft speeds and, more particularly, from the increased *range* of speeds over which aircraft now operate. For example, the speed range of a typical jet fighter varies between 190 and 475 knots (indicated), depending on whether the aircraft is climbing, descending, or cruising. As a result, critical icing temperatures vary widely—say, from −14° in maximum climb near the surface to −2°C. in long-range cruise. Thus it is evident that in modern jet aircraft a pilot report of icing or a forecast of icing has little meaning unless the details under which these conditions occurred or are expected to occur are spelled out. In a similar fashion, Mr. Thompson discussed the turbulence problem, pointing out that the bumpiness which a pilot experiences and reports is a result not only of the true gust velocities but of several other factors, including aircraft speed, weight, wing area, and air density. Since the forecaster is primarily concerned with forecasting only the gust velocity, a basis for relating this parameter to pilot-experienced turbulence is necessary. A set of curves was shown which accomplishes this.

The next paper was given by Charles Anderson on the "Physics of Condensation Trails." These trails are caused by the condensation of moisture in the exhaust and occur and persist under conditions of low ambient temperature and high relative humidity. The theory of jet wake mixing was applied to determine conditions most suitable for trail formation and persistence. Since upper air soundings do not provide information on water content of the atmosphere at higher levels because of failure of the humidity element of radiosondes in extreme cold, it was suggested during the discussion that at least an approximation of the relative humidity might be obtained from the appearance and persistence of trails at these high levels.

In Henry T. Harrison's presentation of "The Display of Hail Echoes on 5.5 cm. Weather Mapping Radar," he showed numerous pictures of air-borne radar echoes with hooks and fingers where simultaneously hail was reported to be falling. These protuberances have a tendency to develop quickly, and a possible explanation was given as the sudden spewing out from the side or overhanging canopy of a cumulonimbus cloud of a hail shaft which falls not into the heart of the storm but on the edge.

A rather impressive collection of statistics was presented by Mr. Harrison to justify his belief that hail can be detected by air-borne radar in 4 out of 5 times, at least in the general area east of the Rockies where United Air Lines' experiments were performed.

The highlight of the next paper, on "Implications of Convective Cloud Observations with Regard to Flight Operations with Air-borne Radar" by Louis Battan, was his suggestion that air-borne radar be modified to scan vertically, as well as horizontally. The advantage of this additional feature is that a pilot, while still at a safe distance from a thunderstorm, can determine the vertical extent of precipitation echoes, their vertical growth, and distribution of echo intensity, all of which are indicative of the severity of the associated turbulence. Vertical scanning will also locate the "bright band"—that is, the altitude at which snow is melting, when such a phenomenon is occurring. Flight above this level will be in snow crystals and hence experience no icing.

The final paper was given by Frank Lewis, Headquarters, Air Weather Service, on "Minimal Flight Path from the Joint Numerical Weather Prediction Units." He described procedures used at the Joint Numerical Weather Prediction Unit in Suitland near Washington, D.C., where the IBM 701 electronic computer is used to predict minimal transcontinental flight paths. This is the computer which is used presently on an experimental basis for predicting pressure patterns for various levels. Such forecasts, already available, are utilized for determining the best time track at the 500-mb. level (about 18,000 ft.). The process requires about 5 min. of machine work. Later the machine will be programmed to provide forecasts at several levels. During the discussion, an interest on the part of some of the air lines was expressed in having these minimal paths and forecast times transmitted over the teletype network for comparison against actual flights now being made several times daily between Los Angeles and San Francisco on the West Coast, and Washington and New York on the East Coast.

Rocket Propulsion

by
D. F. Ferris

Chief, Preliminary Design
Reaction Motors, Inc.

In this session, held jointly with the American Rocket Society, we endeavored to present papers on subjects of mutual interest to aircraft and missile designers and to rocket power-plant people. The papers dealt with the demonstration of reliability in liquid-propellant rocket

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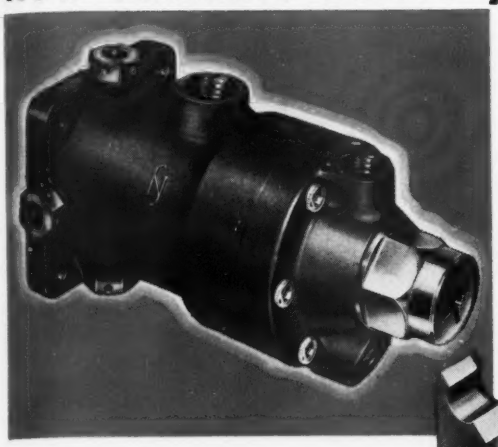

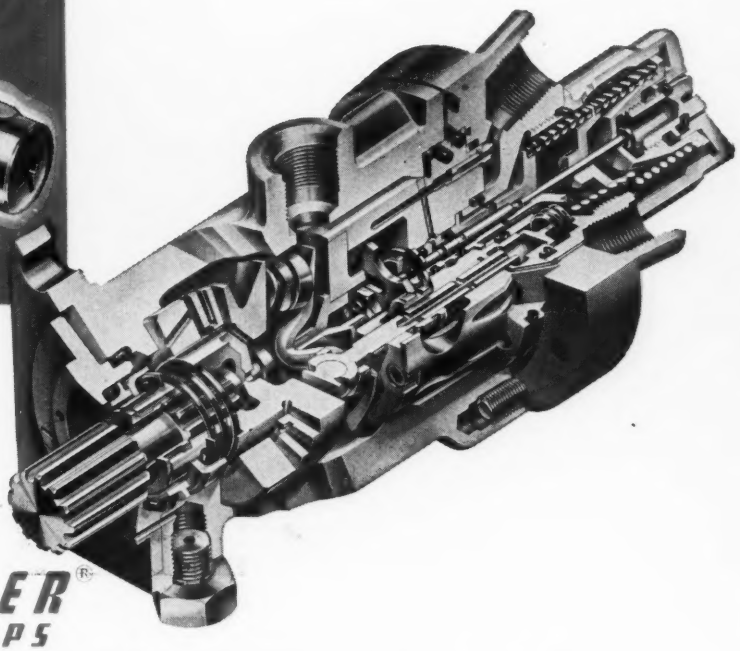

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The problem of achieving and demonstrating reliability in a liquid rocket engine is made difficult, particularly in ballistic missile applications, because of the impossibility of directly monitoring the power plant during flight or of recovering the power plant in the event of an unsuccessful flight. There are means for measuring the performance of a power plant and telemetering these data back to ground during the flight of a missile, but, while this must be used as the final proof of satisfactory operation, it is an extremely expensive and cumbersome approach to use during development. For this reason, there has been increasing emphasis on the study of methods of demonstrating and achieving rocket power-plant reliability during development programs by simulating as nearly as possible combinations of the worst flight conditions and applying statistical methods to hold the required testing within reasonable bounds and yet demonstrate the desired degree of reliability. The paper presented on this subject, entitled "Demonstration of Reliability in Liquid Propellant Rocket Engines," by A. G. Thatcher and H. A. Barton of Reaction Motors, Inc., described a method for testing rocket engine systems by attributes following the methods of sequential analysis. The method was briefly outlined and the test plan discussed.

The task of calculating ballistic missile performance can be a tedious one and is one that must frequently be performed in preliminary design work. It would be desirable to have at hand a means of performing such a calculation with less effort and time. The second paper, entitled "Ballistic Missile Performance," by J. William Reece, R. David Joseph, and Mrs. Dorothy Shaffer, all of the Cornell Aeronautical Laboratory, presented a semianalytical method for calculating the range for one-stage ballistic rocket, surface-to-surface missiles which is applicable over a range of 50 to 500 nautical miles. The authors stated that the method provides a simple approximation to a complex problem and that the results are presented in a form which enables calculations to be made rapidly for use in preliminary design work.

The third paper, entitled, "Improved On-Off Missile Stabilization," by Robert W. Bass of Princeton University, presented a new synthesis procedure for on-off control systems by means of which the delays due to time lag and hysteresis in the relay or contactor can be completely eliminated. Such a system has been used successfully on the Viking rocket in the form of small jets

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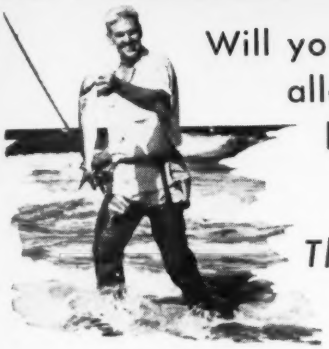

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of decomposed peroxide for attitude control, and it is expected that future ballistic missiles and high-altitude aircraft will make increasing use of this system. It is hoped that this paper will contribute to the ease with which such systems can be analyzed and designed and that it will stimulate further interest in this area.

Structures

by
Walter Ramberg
Chief, Mechanics Division
National Bureau of Standards

This structures session differed from previous structures sessions in focusing attention on the mechanics of fracture in aircraft materials and structures. Four papers were presented.

The first paper, entitled "Fracture Mechanics: The Relation of Crack Extension Force to Onset of Fast Fracturing," was prepared by the well-known team of students of fracture, George Irwin, Waller George, and Joseph Kies. The paper was presented by Mr. George. The authors showed that the stresses near the leading edge of a crack are proportional to $\sqrt{Eg/k}$ where E is Young's modulus and g is a property of the material having the dimensions of stress which the authors call "crack extension force." A high value of g indicates that relatively high stresses are required to produce a rapidly spreading fracture, just as a high yield strength indicates that relatively high stresses are required to produce plastic yielding in ductile materials. The authors concluded with a tabulation of values of g for several aircraft materials. These showed very high values for titanium and much lower values for steels, particularly at temperatures well below room temperature.

The second paper was concerned with the closely related but more specific problem of designing aircraft structures to be more resistant to rapidly propagating fracture or "tearing." The paper was entitled "Some Design Considerations for Tear-Resistant Airplane Structures" and was presented by Arne Sorensen of the Boeing Airplane Company. Mr. Sorensen described tear tests on specimens of various widths up to 30 in. in which cracks were induced artifically by saw cuts, as well as tests of full fuselage sections subjected to fluctuating pressures. A value of "tear resistance" was obtained from these tests by applying an analysis similar to that developed in the previous paper. In all cases, the tear resistance was found to be characteristic of the sheet and was independent of the width of the specimen. The tear resistance increased with increasing sheet thickness. It was greater for stressing in the direction of the grain than at right angles to that direction. It was extremely high for titanium and was greater for 24ST aluminum alloy than for 75ST aluminum alloy. In conclusion, Mr. Sorensen pointed out the effectiveness of heavy stiffeners in stopping cracks and presented general guide lines for designing aircraft structures for greater tear resistance.

The third paper, by L. W. Lassiter, R. W. Hess, and H. H. Hubbard of the NACA Langley Aeronautical Laboratory, dealt with the stressing of riveted panels by intense sounds characteristic of aircraft power plants. The paper, entitled "An Experimental Study of the Response of Simple Panels to Intense Acoustic Loading," was presented by Mr. Lassiter. The authors found that measurements of response of simple panels to the noise from a jet engine at levels of about 160 db. were in agreement with values calculated by the power spectrum procedure due to Miles. Curved panels showed a markedly different response to high sound intensities than flat panels, apparently because of the decrease in stiffness for inward displacements. Radiation damping by absorbent materials near the back of the panels, but not in contact with the metal, had a marked effect on the response. The authors succeeded in producing fatigue cracks with the sound from a laboratory siren. They illustrated this with a film showing the genesis of cracks near rivet holes along the edge of a square panel and the spreading of these cracks into the interior of the panel with continued exposure to the intense sound of the siren.

The last paper was presented by John W. Cox of The Glenn L. Martin Company and was entitled "Structural Behavior of Seaplane Hull Bottom Plating." Mr. Cox began with a film showing landings and take-offs of a flying boat in rough water to bring home the intense transient pressures to which the hull bottom plating is subjected whenever the bottom hits a wave. He then proceeded to show how fatigue tests of small and relatively inexpensive specimens could be used to estimate the fatigue life under the fluctuating pressures characteristic of landing and take-off. The results of fatigue tests on about 300 specimens were plotted as S-N (stress versus cycles to failure) diagrams which were tied in with fluctuating pressure tests on large sheet stringer panels simulating hull bottom construction. The stress distributions and the failures in the small specimens were found to be of the same type as for the large specimens. The tests indicated that extreme fiber stresses of more than 110,000 lbs./in.^{2} can be sustained elastically in 75S-T6 aluminum alloy under the biaxial stress existing in bottom plating under pressure. The paper was concluded with design charts and formulas based on these tests.

The presentation of each paper was followed by comments from at least two discussers from the floor, indicating the constant concern of aircraft designers with the puzzling problem of fatigue fracture in service.

Thermal Stress Analysis

by
George Gerard
Asst. Director, Research Division
College of Engineering
New York University

Overflow attendance at a session devoted exclusively to thermal effects on aircraft structures is indicative of the broad area of new and intriguing problems facing structures engineers in the design of aircraft for hypersonic flight. Three of the presentations at this session were concerned with thermal stresses and the fourth with torsional rigidity losses of aerodynamically heated thin wings.

In "Thermal Stresses and Deformations in Beams," Dr. Samuel Levy presented general formulas for computing thermal stresses and curvature in a long beam when the rise in temperature at any location in the beam cross section is given and when the coefficient of expansion and Young's modulus are known functions of temperature. Computed results are given for both uniform and gradient temperature distributions in rectangular solid and box beams. Simplifying assumptions for computing temperature distributions were suggested and used to derive formulas for determining the temperature, maximum tensile stress, maximum compressive stress, and curvature as a function of time for a wing beam heated from one side.

The presentation by Martin A. Goldberg entitled "Investigation of the Temperature Distribution and Thermal Stresses in a Hypersonic Wing Structure" was viewed from the standpoint of the flux into the system. It was considered to vary sinusoidally with time and to remain constant with position, being equal to the heat flux entering the section at a station midway between the stiffeners of a multicell wing.

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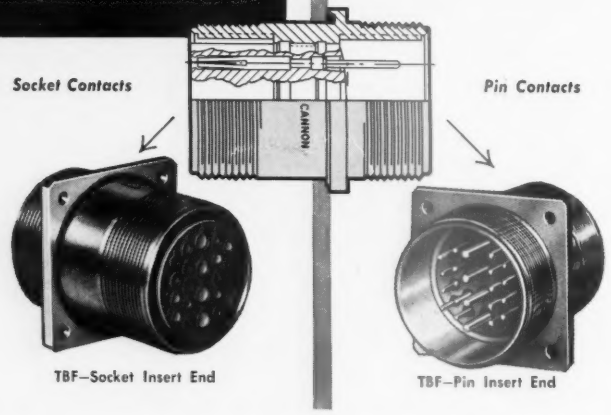

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Temperature and thermal stress distributions were presented in dimensionless parameters for a typical flight plan. The thermal stresses in a multicell section are affected most seriously by the ratio of web depth to the span of the skin. As this ratio increases, the thermal stress in the web passes through a maximum then decreases, whereas the stress in the flange increases, eventually reaching a maximum. The variation of thermal stress caused by changing the other geometric ratios does not appear to be as significant as the above.

Dr. Buford E. Gatewood in "Approximate Procedures for Transient Thermal Stresses in Missile Structures" presented simplified procedures for determining thermal stresses in typical structures. The four-dimensional temperature and thermal stress problem involving time and three space variables was approximated by two idealized structures in which (1) time is the only variable and (2) time and one space dimension are the two variables. The temperature variation and thermal stress variation in these two structures were obtained for various assumed skin temperatures, heat sources, and edge restraints. The results are plotted in a nondimensional form in terms of a nondimensional material, geometry, and time parameter.

Dr. Bernard Budiansky and Jean Mayers discussed the "Influence of Aerodynamic Heating on the Effective Torsional Stiffness of Thin Wings" by noting the loss of torsional stiffness that may result from thermally induced axial stresses. Theoretical results were presented for the effective torsional stiffness of solid wings of symmetrical double-wedge cross section accelerated to supersonic speeds. It was indicated that serious losses of torsional stiffness may occur in such wings. The influence of various parameters such as Mach Number, acceleration, and thickness ratio were discussed.

VTOL Aircraft

by

Capt. William C. Fortune, USN

Head, Air Branch
Office of Naval Research

This session related to short take-off and landing (STOL) or vertical take-off and landing (VTOL) of propeller-driven aircraft in the conventional attitude, not tail-sitting. It was shown by laboratory analyses, design studies, and pictures of actual full-scale model demon-

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stration flights that medium-speed, shorthaul aircraft can be built with these capabilities today. The high thrust to weight ratios which will be attainable soon will foster a new breed to fill in the gap between helicopter and runway-bound, fixed-wing designs of current knowledge.

A summary of the papers presented is given below. Mr. Kuhn gave the NACA paper and Dr. Raspet the Mississippi State College one. W. Stepniewski of the Piasecki Helicopter Corporation reviewed the hovering and pay-load characteristics of the various designs discussed, on the basis of fuel flow per hour per pound of thrust, and pay load to gross weight ratios versus hover times and cruise speeds. A. N. Petroff of Cessna Aircraft Company and Jos. Stuart, III, of Hiller Helicopters had prepared other comments, but time did not permit hearing them. The assistance rendered by Al Satin of the Air Branch, ONR, in arranging the excellent coverage of the papers deserves mention.

"Examination of Some of the Problems Involved in the Design of Propeller-Driven Vertical Take-Off Transport Airplanes," by Marion O. McKinney, Jr., Richard E. Kuhn, Jerome B. Hammack, all Aeronautical Research Scientists, Langley Aeronautical Laboratory, NACA, was the first paper. For the past 5 years, research especially applicable to propeller-driven vertical take-off transport airplanes has been under way at the Langley Aeronautical Laboratory. This paper summarized this work, which covers stability and control, propellers, and the aerodynamic characteristics of wing-propeller combinations. The paper concluded with an illustrative example of a hypothetical airplane design laid out on the basis of information available to date and indicates that it is possible to design a vertical take-off transport airplane with a useful degree of performance.*

The next paper dealt with "Some Considerations of the STOL Airplane" and was written by Walter Tydon, Chief Engineer, Fairchild Aircraft Division, Fairchild Engine and Airplane Corporation. It gave the concept of a STOL airplane and typical performance objectives for the transport category. Past developments were reviewed and certain major design problems delineated. For example, the new landing technology, such as forced circulation vectored slipstream and tilting propellers of possible application to these problems, was discussed. Apparent advantages of the STOL airplane over VTOL types were pointed out, and a résumé of needed additional research was presented.

"An Application of the Ducted Propeller to a Vertical Take-Off Transport Airplane," by James A. O'Malley, Jr., Project Aerodynamicist, Bell Aircraft Corporation was read next. This paper applied the concept of vertical take-off and landing, which has been developed with the Bell jet VTOL air test vehicle, to a medium transport airplane powered by ducted propellers. The application of this type of horizontal attitude VTOL configuration to the transport category was discussed and the feasibility of using ducted propellers developed in terms of hovering efficiency and cruising economy. The general characteristics of hovering transition stability and control between jet and ducted propeller types were emphasized, and the feasibility of reaction control devices and manual control during hovering were considered.

A typical VTOL transport configuration was presented. This airplane was discussed in terms of gross weight, pay load, range speed, take-off, and landing performance. A typical operational site was discussed.

The highlights of the Bell jet VTOL experiments with the air test vehicle were illustrated by flight-test movies of this airplane, and the application of these experimental findings to the transport configuration was delineated.

"Delay of the Stall by Suction Through Distributed Perforations," by August Raspet, Head; J. J. Cornish, III, Aerodynamicist; Glenn D. Bryant, Aeronautical Engineer; all of the Aerophysics Department, Mississippi State College, was the concluding paper of the session.

Considerable effort had been applied to high lift boundary-layer control in Germany. This work is well summarized by Stuper in NACA TM 1232. Since the war, domestic interest in this work has been inspired by the Air Branch, ONR, notably in the application of the Arado system to the Cessna 170 and the Cessna L-19. In general, both the single slot system reported by Stuper and the Arado system were found to be extravagant of energy for the boundary-layer control system.

The system using distributed suction through perforations permits an ultimate economy of boundary-layer control power to be obtained. In this paper the authors described the method for designing the suction distribution which permits high lift to be obtained on a small airplane with a suction power of only 2 hp. The performance of a Piper L-21 modified for such a system is such that the take-off distance over a 50-ft. obstacle is reduced by 42 per cent with the suction power taken from the engine.

A perforated surface suction boundary-layer control system applied to the Fairchild C-119 was also described. Preliminary design calculations illustrate both the economy of suction power and the lift augmentation of the system.

* "Problems in the Design of Propeller-Driven Vertical Take-Off Transport Airplanes," by M. O. McKinney, R. E. Kuhn, and J. B. Hammack, appears in full in this issue on pp. 68–75.

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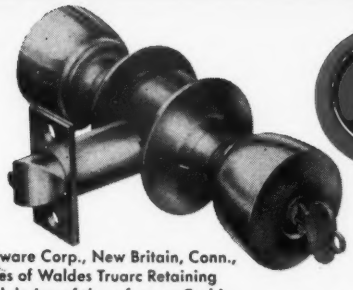

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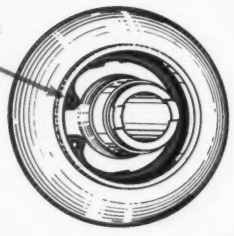

Truarc Beveled Ring (Series 5002) couples the knob to the knob shank. It eliminates two tapped holes and two screws, provides stronger assembly and greater accuracy. Beveled ring takes up end play rigidly.

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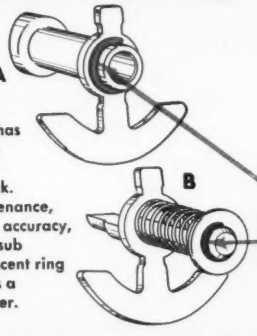
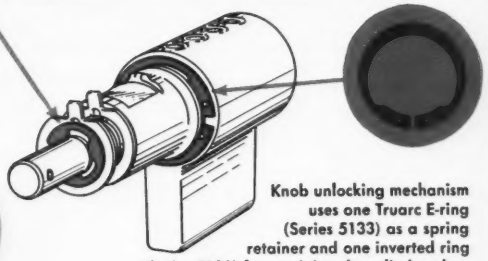


Spindle sub assembly "A" has two Waldes Truarc crescent rings (Series 5103) used as locating flanges for rollback. This saves labor and maintenance, improves performance and accuracy, eliminates rejects. Spindle sub assembly "B" uses one crescent ring as a spring retainer and as a locating shoulder for washer.

Cylinder Sub Assembly



Knob unlocking mechanism uses one Truarc E-ring (Series 5133) as a spring retainer and one inverted ring (Series 5108) for retaining the cylinder plug. Rings are re-usable in the event of disassembly for maintenance. Rejects are eliminated.

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IAS News

(*Continued from page 37*)

Harold E. Bauer (M), of Douglas Aircraft Company's Santa Monica Division, has been promoted to Field Station Supervisor at Holloman Air Development Center, Holloman AFB, N.M.

Arnold R. Beckhardt (M) has been promoted to Project Engineer at the Airborne Computer Laboratories of International Business Machines Corporation.

William O. Boschen (AM), Vice-President—Sales, Avien, Inc., has been named Assistant General Manager, as well.

E. J. Catchpole (TM), formerly a Stress Analyst with Vickers-Armstrongs Ltd., Weybridge, England, has joined Aero Research Limited, Duxford, Cambridge, as Personal Assistant to the Managing Director.

Joseph J. Dysart (AF) has been appointed Assistant Chief Project Engineer for the DC-8 jet transport at the Santa Monica Division of Douglas Aircraft Company, Inc. Previously, he was Assistant Chief Project Engineer for the DC-7 series.

George M. Goldman (AF) has joined Avco Manufacturing Corporation as Head of the Operations Analysis Section, Advanced Development Division. He was formerly Chief of the De ign Criteria Section, Structures Branch, Aircraft Laboratory, WADC, Wright-Patterson AFB.

Frederick H. Guterman (M) has been named Assistant Vice-President of the Arma Division of American Bosch Arma Corporation. Previously, he was Assistant Vice-President for Sales.

Lloyd W. Harris (M) has been promoted to Assistant Chief Pilot of Lockheed Aircraft Corporation's Georgia Division.

Emerson W. Conlon, FIAS, has been named General Manager of Curtiss-Wright's newly acquired Turbomotor Division. He was formerly with Fairchild Engine Division.

Edmund T. Price, MIAS, has been elected Chairman of the Board of Solar Aircraft Company. He was formerly President and General Manager.

Major Donald H. Hilker, USAF (TM), has been appointed Chief of the Management and Resources Division, Directorate of Procurement, Headquarters ARDC, Baltimore. He was formerly stationed at Wright-Patterson AFB, where he completed the USAF Institute of Technology's graduate course in Engineering Administration.

Major J. Vivian Holman (M), of Chalfonte St. Peter, Bucks, England, has been appointed Aeronautical Consultant to The General Fire Appliance Company Ltd., of New Addington, Surrey.

Oscar E. Holt (M) has been appointed Manager of the Old Forge Plant of The W. L. Maxson Corporation. He was formerly Manager of Electro-Mechanical Engineering.

Group Capt. John A. Kent, RAF (M), formerly Commanding Officer of the RAF Station at Tangmere, Sussex, England, has been appointed Senior Officer in Charge of Administration at Headquarters No. 12 Group Fighter Command, Newton, Nottinghamshire.

Frank E. Marble (M), Associate Professor of Jet Propulsion at California Institute of Technology, is visiting professor this spring in Cornell's Graduate School of Aeronautical Engineering at Ithaca, N.Y.

John W. Myers (M), a former Vice-President and Director of Northrop Aircraft, Inc., has been elected to the Board of Directors of Hewitt & Faust Manufacturing Company, San Diego, Calif. He is an attorney and former test pilot.

J. Gilbert Nettleton, Jr. (AM), has been elected Vice-President of the Radioplane Company. He is in charge of customer relations and continues to serve as Assistant to the President. A former production test pilot, Mr. Nettleton joined Northrop Aircraft, Inc., of which Radioplane Company is a subsidiary, in 1946.

John O. Powers (TM) has been promoted to Manager—Aero-Thermodynamics Engineering, in the Special Defense Projects Department, General Electric Company, Schenectady, N.Y.

Ralph W. Rawson (M) has joined Fansteel Metallurgical Corporation as Chief Engineer. As a Commander in the Navy, he was, until recently, Director of the Industrial Planning Division of the Bureau of Aeronautics, Wright-Patterson AFB.

R. E. Small (TM), former Manager—Marketing for the Jet Engine Department, Aircraft Gas Turbine Division, General Electric Company, has been placed in charge of G-E's European Technical Service Office established recently by the AGTD in Paris.

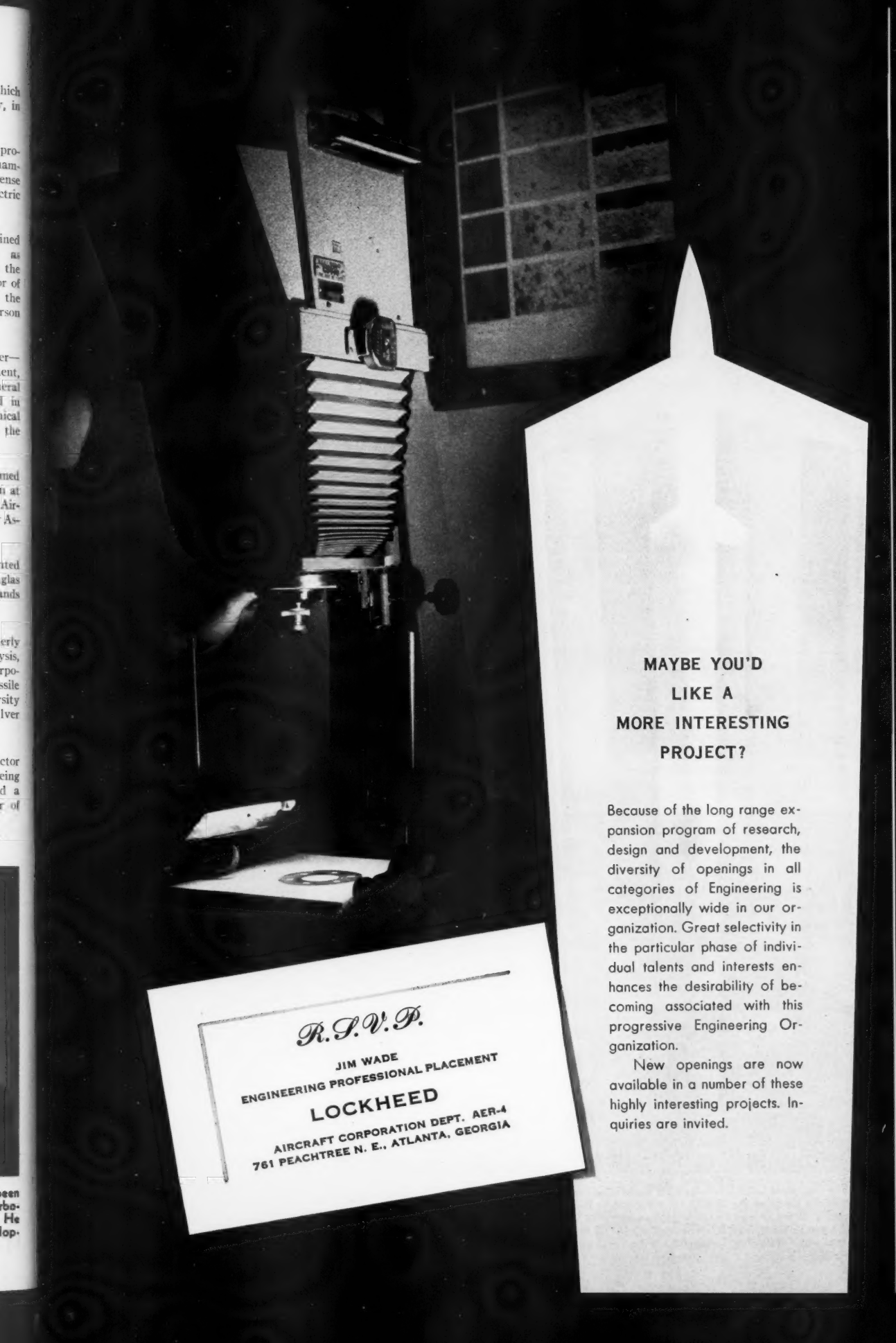
Robert B. Smith (M) has been named Chief of a new Design Studies Section at the El Segundo Division of Douglas Aircraft Company, Inc. He was formerly Assistant Chief of Aerodynamics there.

E. L. Sorenson (M) has been appointed Field Station Supervisor for Douglas Aircraft Company, Inc., at White Sands Proving Ground, N.M.

Ludolph F. Welanetz (M), formerly Chief Engineer—Plans and Analysis, Fairchild Camera and Instrument Corporation, is now engaged in guided-missile research at The Johns Hopkins University Applied Physics Laboratory in Silver Spring, Md.

Lysle A. Wood (AF), formerly Director of the Pilotless Aircraft Division of Boeing Airplane Company, has been named a Vice-President and General Manager of this division.

Norman C. Witbeck, MIAS, has been appointed Chief Engineer of the Turbomotor Division, Curtiss-Wright Corp. He was formerly with the Research and Development Board.



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CORPORATE MEMBER NEWS

• **Allis-Chalmers Manufacturing Company** is building three centrifugal compressors and associated drive equipment to be used in a 4 by 4 ft. supersonic blowdown tunnel to be constructed at the Convair plant in San Diego, Calif. . . . A 24-page directory of product literature, *This is A-C from A to Z*, has been released by Allis-Chalmers.

• **Allison Division, General Motors Corporation . . .** Aeroproducts turbopropellers will be used on the Lockheed C-130A Hercules cargo plane which has four Allison turboprop engines. . . . Allison Division produced its 100,000th aircraft engine in January, the company announced.

• **Aluminum Company of America. . .** Additional smelting facilities have been placed in production at Rockdale and Point Comfort, Tex. When completed, the expansion program will boost the combined capacity of the two plants by 75,000 tons of primary aluminum annually. . . . Alumicone, a new paint containing aluminum pigments in a silicone-alkyd resin base, withstands temperatures over 1,500°F. Developed for aircraft applications, it can be sprayed or brushed on engine exhaust stacks or other metal surfaces subjected to intense heat. . . . A 134-page, illustrated book on brazing aluminum is available from Alcoa.

• **American Airlines, Inc. . . .** The Buffalo reservation office has been linked to American's "magnetronic reservisor" at LaGuardia Field, New York. This marks the first time in travel history, the air line claims, that an agent in one city, by pressing a button, has been able to complete or cancel a ticket sale based on information stored in inventory in a remote city. The electronic reservations system, which "memorizes" the inventory of seats for a 10-day period, has been in local operation at LaGuardia since 1952.

• **Arma Division, American Bosch Arma Corporation. . .** An illustrated booklet describing Arma's Subminiature Gyro Compass, which weighs 30 lbs., is available from Arma Division, Garden City, N.Y. Intended for naval and military use on ships of all sizes and on land and amphibious vehicles, the compass can be adapted for use on light planes, fighters, and helicopters.

• **Avien, Inc.,** announces a portable 400-cycle power supply designed for field use in testing and servicing aircraft instrument systems. The size of a large brief case, it weighs 7 lbs. and operates from any 115-volt, 60-cycle line.

• **Bendix Aviation Corporation. . .** Friez Instrument Division reports commercial development of the Lumicon, a device that amplifies light 40,000 to 50,000 times by electronic means. It can reveal a blacked-out scene as a bright television picture. Linked with X-ray, it projects a bright "alive" image on a television screen with only a low-level output of X-ray energy. The Lumicon is expected to open new fields in industrial and medical radiography, astronomy, and photography. It will make possible immediate X-ray inspection of forgings, castings, engines in operation, and similar large objects. The Lumicon is far more sensitive to light than the human eye. . . . Bendix Products Division has built a mobile instrument laboratory in a truck-trailer to take advantage of telemetering techniques in testing aircraft and automobiles while in motion. Instead of observing the performance of a jet engine in a test cell, for example, laboratory-type test equipment can be "connected" by radio telemeter to an engine in actual flight. While the jet plane climbs, dives, and maneuvers at various speeds and altitudes, sensitive pickup devices on the plane will register engine speeds, internal pressures, temperatures, rates of fuel flow, and other pertinent data. These are converted into radio signals and instantly recorded by receiving apparatus on the ground. One advantage of this system is the immediate availability of data on a large plotting board. . . . A new documentary motion picture, *Air Power '56*, is available from Bendix Products Division, South Bend, Ind. The 16-mm. color sound film was made at the last National Air Show in Philadelphia.

• **Boeing Airplane Company** has announced a $29,500,000 program for expansion of facilities. Financed entirely by the company, the building program calls for a $21,000,000 Developmental Center at the main plant in Seattle and an $8,500,000 manufacturing and office facility at nearby Renton, Wash. The Developmental Center, to be completed by the fall of 1957, will be adjacent to Boeing Field and will add 1,021,000 sq.ft. of covered area to the Boeing plant. The largest of the four main buildings will have a floor area of 754,000 sq.ft. The Developmental Center will be occupied by certain phases of the Bomarc project and by physical research, structural testing, and experimental activities. The Renton facility, with 558,000 sq.ft., will be used for assembly of body sections of the 707 commercial jet transport. It also will house Boeing's newly created Transport Division. J. B. Connelly has been named Vice-President and General Manager of this division which is responsible for the KC-135 and KC-97 tanker-transports and the commercial 707's. . . . A newly organized Seattle Division, headed by Vice-President C. B. Gracey, has assumed responsibility for the B-52 eight-jet bomber and other major developmental projects.

• **The Cleveland Pneumatic Tool Company** has purchased the National Water Lift Company, Kalamazoo, Mich., which designs and manufactures control mechanisms for aircraft and guided missiles. The announcement said that National Water Lift will continue as a division of Cleveland Pneumatic under its present management, headed by C. E. Willis, MIAS.

• **Douglas Aircraft Company, Inc. . . .** The first C-133A turboprop cargo plane to be completed for the Air Force was rolled out of the hangar at Douglas' Long Beach plant on February 2. The giant four-engined plane has a gross weight of 255,000 lbs. and can carry twice the pay load of the Douglas C-124 Globemaster II, which has a gross weight of 185,000 lbs. Its wing span is 179 ft. 8 in. The cabin for air freight is 90 ft. long and accommodates most military vehicles. The cabin is pressurized and can be modified to hold 200 troops. The C-133A is powered by four Pratt & Whitney T34-P-3 turboprop engines driving three-bladed Curtiss-Wright Turbolectric pro-

The first giant C-133A turboprop cargo plane to be completed for the Air Force is rolled out at the Douglas Aircraft Company plant in Long Beach, Calif. With twice the pay-load capacity of the Douglas C-124 Globemaster, the C-133A has a gross weight of 255,000 lbs. and a wing span of 179 ft. The fuselage is 148 ft. long, and the cargo hold is 90 ft. A crew of four will handle this global air freighter.

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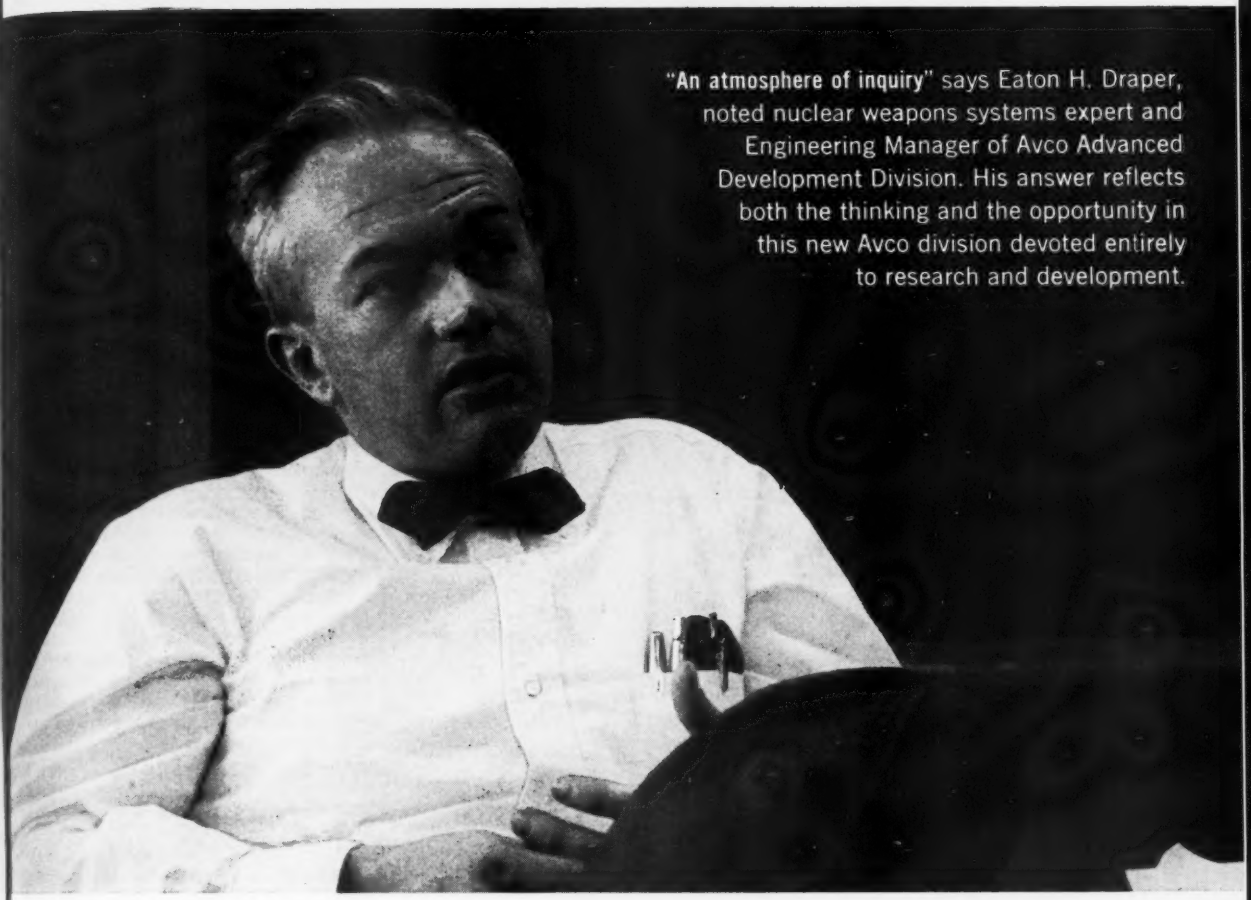

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pellers. . . .The Douglas RB-66 jet bomber, designed for all-weather reconnaissance missions at speeds of 600 to 700 m.p.h., is now being delivered to the 363rd Tactical Reconnaissance Wing of the Ninth Air Force at Shaw AFB, S.C. . . .Douglas has completed delivery of 166 C-118A's and R6D-1's, military and naval versions of the DC-6 transport.

• **Fairchild Camera and Instrument Corporation** has opened a new plant at 6111 East Washington Blvd., Los Angeles.

• **Fairchild Engine and Airplane Corporation . . .**The American Helicopter Division in Costa Mesa, Calif., has been renamed the Fairchild Electrotechnics Division. This name was considered more appropriate for describing the Division's activities in the fields of (1) resistance-welded, temperature-resistant sandwich material for aircraft, (2) automatic instrumentation components and systems for aircraft and industrial applications, and (3) lightweight Fiberglas-reinforced plastics microwave "plumbing" for radar systems. Development work on STOL and VTOL aircraft has been transferred to the Fairchild Aircraft Division in Hagerstown, Md. . . .Fairchild Aircraft Division has placed on the market the Speedy Driller, a versatile, high-speed, semiautomatic drilling machine that is expected to prove useful in the aircraft and automotive industries. The portable machine is particularly adapted to drilling metal parts requiring a large number of holes closely spaced. It drills rivet holes in 0.064 aluminum sheet at the rate of three per sec.

• **The Garrett Corporation** has completed a $5,000,000 production test facility in Phoenix, Ariz., adjacent to the AiResearch Manufacturing Division. With 90,000 sq.ft. of working area, the new laboratory has test cells, altitude chambers, a cold chamber, dynamometers, and other devices for testing gas-turbine engines, air turbines, pneumatic controls, air valves, and related aircraft components and systems. Altitudes up to 75,000 ft. can be simulated. Temperatures range from −80°F. to 1,000°F. Altogether, there are more than 75 production test cells and test stands. An elaborate plumbing system supplies compressed air at up to 1,000 lbs. per sq.in.

• **General Electric Company. . .**New multimillion dollar development facilities of the Aircraft Gas Turbine Division in Cincinnati were unveiled February 9 to a group of military and industrial leaders. In an all-day tour, the visitors were shown equipment for testing virtually every part of a jet engine; computers for high-speed mathematical calculations; methods used in developing advanced fuels, alloy metals, and plastics; and numerous other facilities constructed during the past 5 years. One of the exhibits was a half-scale cutaway model of a rocket engine similar to the one G-E will build for the Project Vanguard satellite rocket. . . .G-E's T58 small gas-turbine engine is in advanced stages of development for the Navy's Bureau of Aeronautics and is rated "in the 1,000-hp. class," the company revealed recently. Intended for use in helicopters, the T58 incorporates the "free" power turbine design which pro-

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vides increased stability of operation as a result of its favorable torque-speed characteristics and permits greater flexibility in the selection of rotor speeds. Several types of fuel can be used. According to the Small Aircraft Engine Department, the T58 will offer great advantages over equivalent piston engines in endurance, pay load, and other performance features.

• **G. M. Giannini & Co., Inc.,** has established a new Controls Division at 969 North La Brea Ave., Hollywood 38, Calif. Acquired from Brinkman Manufacturing Co., Inc., the new facility is well equipped to manufacture high-precision aircraft servocontrols.

• **The Goodyear Tire & Rubber Company Inc. . . .** Under a contract with the Navy's Special Devices Center, Goodyear Aircraft Corporation has developed a radar simulator for training pilots in the tactical use of all-weather radar equipment. Tied in with an operational flight trainer, the new equipment requires a tactics instructor housed in a mobile trainer. The instructor can study a student's use of radar as he intercepts enemy aircraft. He can simulate numerous conditions for the pilot, as well as set initial conditions of the tactical radar problem. He can insert whatever evasive action he thinks enemy aircraft would employ. . . . The Aviation Products Division has developed a watermelon-shaped rubber tank that could revolutionize the bulk transportation and storage of fuels and other liquids. Called the Rolli-Tanker, the nylon-reinforced container can be rolled over uneven, swampy, or sandy ground; floated in rivers; and dropped a few feet without bursting. With a capacity of about 250 gal., the Rolli-Tanker contains an axle that permits it to be towed by a vehicle. It also can be rolled by hand. . . . Goodyear Aircraft Corporation announces a new analog computer, the GEDA Model A14, that combines virtually unlimited linear and nonlinear computing capabilities with great accuracy, flexibility, and simplified operation.

• **Grumman Aircraft Engineering Corporation. . .** A convertible passenger-cargo version of the S2F sub-killer has been designed for the Navy. Known as the TF-1, the twin-engined plane carries nine passengers in rearward-facing seats. It is equipped with the latest navigational devices and will be used as an all-weather, carrier-based trainer for Navy pilots. Its principal service will be as a carrier resupply craft, ferrying passengers and cargo between ship and shore. To offset the strain placed on tie-down lines during an arrested carrier landing, Grumman engineers designed a "cage" to trap the cargo load in a fixed position. Two parallel sets of movable vertical bulkheads are installed between longitudinal rails, one attached to the overhead and the other to the deck. Vertical side posts may be inserted at any point along the length of the cage, depending upon the size of the load. This device will trap the cargo until force exerted by the load reaches 20g's.

• **Harvey Aluminum Division of Harvey Machine Co., Inc. . . .** New hydraulic forging presses being installed in the plant at Torrance, Calif., are expected to make possible aluminum-alloy hand forgings weighing up to 2 tons. These massive hand forgings, the company says, will satisfy the most extended weight, dimensional, and metallurgical requirements anticipated by air-frame manufacturers.

• **Lockheed Aircraft Corporation** has announced plans for construction of a group of research laboratories on a 22-acre site at Stanford University, Palo Alto, Calif., for advanced scientific studies in the realm of missiles and unmanned aircraft. Contracts have been let for design and construction of two new research laboratories for the Missile Systems Division at Stanford. A manufacturing plant of 96,000 sq.ft. will be built for the same division on a 275-acre site at nearby Sunnyvale. The company plans to spend $7,000,000 on the first two laboratories at Stanford's industrial park and on initial construction at Sunnyvale. These projects were said to be the first steps in a program calling for investment by Lockheed of "approximately $20,000,000 in the next 3 years."

• **Manning, Maxwell & Moore, Inc. . . .** The Industrial Controls Division announces a new line of graphic-type recording millivoltmeters and microammeters, the American Microsen Series 130 Electronic Recorder. With a measuring element that is more than 50,000 times more powerful than conventional direct-deflection movements, the pen drive mechanism has ample power to operate alarm contacts with no loss of accuracy.

• **North American Aviation, Inc. . . .** The supersonic F-100D Super Sabre—first jet fighter to use Minneapolis-Honeywell's MB-3 autopilot—has passed its first flight tests, the company announced. Like the A and C models, the plane is powered by a Pratt & Whitney J57 turbojet engine with afterburner. More than 550,000 engineering man-hours and 4,670 engineering drawings were required to produce the F-100D. . . . A powerful electrodynamic vibration exciter has been installed in North American's Environmental Laboratory at Downey, Calif. This "big shaker," which weighs 9 tons and costs $80,000, can subject equipment intended for supersonic aircraft and guided missiles to 45 times the force of gravity. It has a continuous rated force output of 12,500 lbs. Although the Laboratory has 30 other vibration exciters, the new one is remarkable for its high force output and large-item capacity. Features of the new system are sinusoidal table motion, relatively resonant-free operation, and a rotary power supply. Its operating frequency range is from 2 to 2,000 cycles per sec. . . . The Atomics International Division is building a sodium-graphite pilot-plant reactor which is expected to supply surplus heat for the generation of electricity for public consumption this summer. The experimental plant is located in the Santa Susana mountains 30 miles from Los Angeles.

• **Nuclear Development Corporation of America** is conducting studies for the Army Transportation Research and Development Command to determine the technical feasibility of applying nuclear power to Transportation Corps equipment used in land and water operations. Items to be considered include certain rail locomotive equipment, several types of Army harbor and inland waterways craft, and large cargo-carrying land vehicles known as "land trains."

• **Pan American World Airways, Inc. . . .** An automatic reservations system will be installed this spring in Pan American's eight New York City ticket offices. By inserting a plate into the device and pushing buttons, the ticket agent will be able to learn immediately what space is available on any given flight. The central information rack of the electronic system is capable of storing information on 700 flights for 1 month in advance. The system can be used for reserving cargo space, as well as passenger space, and will later be extended to some of P.A.A.'s other offices in the United States.

• **The Parker Appliance Company** announces O-rings made of a new synthetic rubber material for static-seal applications. The new Parker Compound No. 66-103 was developed to meet a demand from aircraft manufacturers for seals suitable to use with MLO-8200 and Monsanto OS-45 fluids at temperatures from −65°F. to 400°F. . . . Parker has issued a 12-page catalog, No. 5701, containing cross-reference charts of size numbers with dimensional data for all Parker O-rings for sealing applications.

• **Pesco Products Division, Borg-Warner Corporation. . .** Robert G. Hess, Vice-President—Operations, has been promoted to Executive Vice-President.

• **Radioplane Company** has developed a radio-controlled plastic target drone as an independent, privately financed research project. Named the RP-77, the medium-speed drone has been designed for economical large-scale production. Glass-fiber cloth is applied in layers, bonded, and reinforced by polyester resins. The smoothness of this material reduces drag. Moreover, the plastic-bonded, glass-fiber cloth possesses high impact resistance, an important consideration because the drones are recovered by parachute and used again and again. The target plane flies 350 to 400 m.p.h. and goes to high altitudes. It can be converted easily to a camera plane for battlefield reconnaissance. Radioplane Company built the first plastic drone, the Air Force XQ-10, and is presently manufacturing the OQ-19. The company has delivered more than 40,000 pilotless aircraft to the Armed Forces.

• **Republic Aviation Corporation** reports satisfactory tests of a new muffler used to reduce the noise of jet engines operating on the ground. Microphones and recording equipment were set up at various points in the community surrounding the airport. It was found that, to the ear of an airport neighbor, the muffled roar of an engine run-up at full power was no worse than the noise of nearby automobile traffic. Republic has ordered four more muffler units to join the experimental one now in use at its airfield in Farmingdale, N.Y. The muffler is large and unwieldy but can be moved to various locations on the field. The tailpipe of the jet plane is placed in one end, and, after about 75 per cent of the noise is eliminated by sound-

LEAR PRODUCES *for t*

This roster of Lear aviation products is, of necessity, incomplete. Many of these products are frequently combined to form an infinite variety of additional products or systems. Only enough typical devices are shown here to demonstrate Lear's mastery of a field of science and technology that uses thousands of such building blocks for meeting the highly specialized requirements of modern aircraft and missiles.

δ *flight control systems*

Automatic altitude controllers
Automatic approach couplers
Automatic Mach number controllers
Automatic pilots (lightplane)
Automatic pilots (high-performance)
Automatic pitch, yaw, and roll dampers
Automatic rudder controllers
Automatic wing flap systems
Missile control systems
Test equipment

σ *flight reference systems*

No-gimbal-lock vertical gyro indicators
Stable platforms
Test equipment
Three-axis gyro indicators
Vertical gyro indicators

γ *navigational systems*

Automatic radio direction finders
Glide slope receivers
High-latitude gyro compass systems
Integrated ADF-magnetic compass systems
Localizer receivers
Marker beacon receivers
VHF Omnirange receivers

ξ *electro-mechanical systems*

Artificial feel systems
Camera positioners
Canopy control systems
Carburetor air door controllers
Convertiplane rotor positioning systems
Cowl flap positioners
De-icing valve positioners
Engine throttle controllers
Gas, hydraulic, fuel, valve positioners
Inlet screen retraction systems
Inlet vane angle controllers
Jettison systems
Landing gear lock systems
Mechanical advantage ratio changers
Oil cooler flap controllers
Parachute door systems
Precision remote positioning systems
Supercharger blower shifters
Test equipment
Throttle friction controllers
Trim tab positioners
Turbo-prop clutch valve controllers
Wing flap positioning systems

λ *electro-mechanical components*

Linear actuators
Rotary actuators
Servo actuators
Power units
Actuator controls
Alternators
Capstans
Freewheeling clutches
Friction clutches
Magnetic clutches
Slip overload clutches
Electromagnetic brakes
Flex drive H's, hex's, L's, and T's
Flexible shafts
Gearboxes
Handcranks
Motors (AC and DC)
Enclosed fan motors
Explosion proof motors
Gearhead motors
High frequency motors
High temperature motors
Miniature motors
Pneumatic motors
Servo motors
Torque motors
Screwjacks
Load limit switches
Position limit switches
Programming switches

ζ *instruments*

ADF indicators
Attitude indicators, 2-axis
Attitude indicators, 3-axis
Directional indicators
ILS indicators
Integrated ADF-magnetic indicators
Trim indicators
Tuning meters
Omnirange indicators

μ *instrument components*

Altitude transducers
Vacuum tube amplifiers
Magnetic amplifiers
Printed and etched circuit amplifi
Transistor amplifiers
Displacement gyros

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Magnetic modulators
Magnetic powder clutches
AC and DC servo motors
Electric gyro motors
Flag motors
High-frequency motors
Torque motors
Power converters
Rate generators
Rate gyros
Resolvers
Synchros
Synchro repeaters

ψ *communications systems*

UHF, VHF, HF, MF, and LF receivers
VHF transceivers
VHF, HF, and MF transmitters
ADF receivers
Airport traffic transceivers
Monitoring transceivers
Portable transceivers
Telemetering receivers
Test equipment

ε *communications components*

Audio frequency amplifiers
Vacuum tube amplifiers
Magnetic amplifiers
Power amplifiers
Printed and etched circuit amplifiers
Transistor amplifiers
Aircraft broadband antennas
Ground plane antennas
LF-MF whip antennas
Loop antennas
Mobile antennas
Trailing wire antennas
UHF-VHF whip antennas
VHF Omnirange antennas
Antenna fairleads
Antenna reels
Antenna tuning coils
Cable assemblies
Coil assemblies
Crystals
Dynamotors
Headsets
Loudspeakers
Amplifying loudspeakers
Noise-cancelling microphones
Radio noise filters

ϕ *test equipment*

Bench test cable assemblies
Electronic test sets
Field strength meters
Pressurizing test kits
Universal electro-mechanical test stands
Universal motor test stands

η *fluid handling equipment*

Absolute pressure switches
Bombsight and instrument desiccators
Canopy seal pressurizing kits
Cooling units for electronic assemblies
Dehydrators
Fuel flow dividers
Pneumatic actuators
Pressurizing control panels
Alcohol pumps
Anti-detonant injection pumps
Ballast pumps
Bilge and refueling pumps
Dry air pumps
Electric motor driven pumps
Ethylene glycol and coolant pumps
Ethylene oxide pumps
Fuel pumps
Fuel booster pumps
Fuel filter de-icer pumps
Fuel transfer pumps
Hand operated pumps
Heater fuel pumps
Hydraulic pumps
Hydraulic oil booster pumps
Hydrogen peroxide pumps
Lube oil and scavenge pumps
Multiple-element pumps
Oil transfer pumps
Scavenge pumps
Smoke pumps
Submerged fuel booster pumps
Vacuum pumps
Water pumps
Radar pressurizing kits
Rocket engine fueling nozzles
Air relief valves
Check valves
Hydraulic valves
Hydraulic servo valves
Isobaric relief valves
Pressure regulating valves
Vacuum valves

π *miscellaneous*

Airborne television installations
Airplane brake modernization kits
Auxiliary power supplies
Electronic chassis assemblies
Executive airplanes
Periscope prism selectors
Precision remote positioners
Printed circuits
Radomes
Wire harnesses

LEAR Lear

CP-13

Rapids, Iowa • Cal Division: Santa Monica, Calif. • Lear-Romec Division: Elyria, Ohio • Aircraft Engineering Division: Santa Monica, Calif. • Lear International, Inc.: N.Y.C.

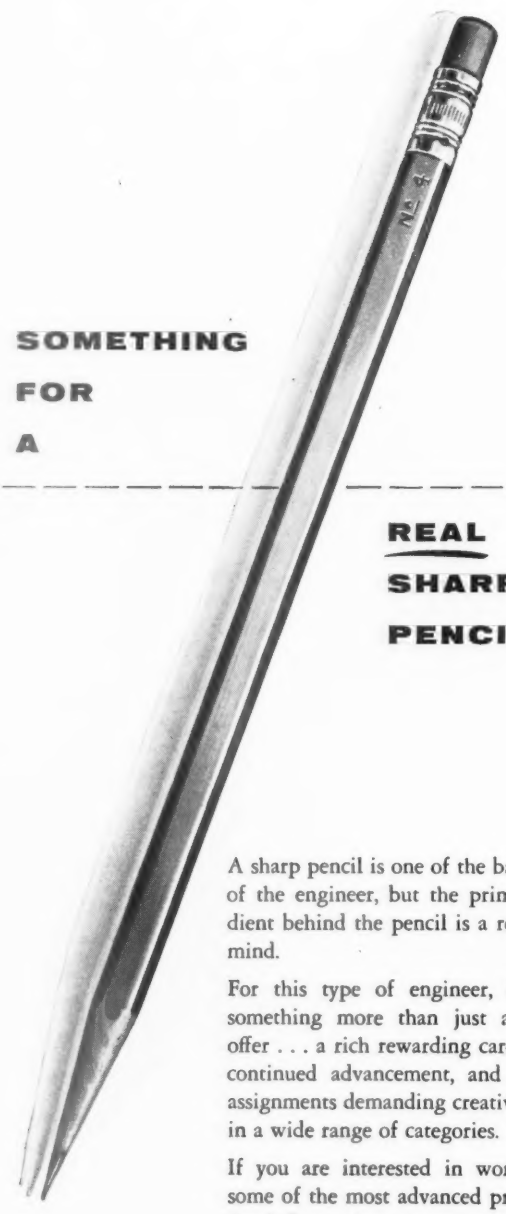
absorbing chambers, the remainder is emitted skyward at the other end. . . . Republic has sold all rights to its Seabee light amphibian to J. K. Downer, of Saginaw, Mich. More than 1,000 Seabees were built in 1946 and 1947, and most of them are believed to be still in use. Mr. Downer has formed a company at Tri-City Airport, Saginaw, to provide spare parts and service to owners of the four-place, all-metal amphibian.

• **Solar Aircraft Company** has completed a new Engineering Office Building and an Engineering Test Laboratory on its bay-front site in San Diego, Calif. The Engineering Division, which has expanded 50 per cent in the past year, now has 27,000 sq.ft of floor space—three times the amount previously occupied. The office building is lighted by a luminous ceiling, and its windows are shaded automatically by electronic devices actuating motor-driven jalousies. The jalousies admit maximum outside light without direct sunlight. The laboratory building contains five test cells, bringing to 19 the number of Solar test cells for the research, development, and production testing of gas-turbine engines. The laboratory also has an 1,800-hp. diesel engine as a special power source. . . . Solar conducted a symposium in February at its Des Moines, Iowa, plant for representatives of titanium producers and suppliers.

• **Thompson Products, Inc.** . . . The Electronics Division announces a new air-borne wave-guide switch for the microwave field.

• **United Air Lines, Inc.,** the nation's oldest air carrier, on April 6 celebrated the thirtieth anniversary of the first scheduled air-mail flight by Varney Air Lines, its predecessor.

• **United Aircraft Corporation.** . . Synchrophasing, an electronic system for keeping the propellers of multiengined aircraft "in step" with split-second accuracy, has been perfected by Hamilton Standard Division. It will be applied to the Lockheed 1649A Super Constellations ordered by Trans World Airlines, Inc., according to an announcement by Erle Martin, FIAS, General Manager of Hamilton Standard. When synchrophased, all propellers turn at a specified angular relationship to each other. This marks a logical step beyond the company's earlier development of synchronization, which holds all propellers at the same number of r.p.m. The result is a considerable reduction of noise and vibration within the airplane cabin. Synchrophasing is accomplished with only 60 lbs. of electronic gadgetry. A magnet is installed on each propeller and a coil in each engine nacelle. When a magnet passes a coil, it sets up a voltage pulse which represents each blade angle. This impulse travels to an electronic control which compares the time of the impulses from each nacelle. If the timing of the pulses differs by even an extremely small fraction of a second, the difference is registered and corrected. Thus the propellers are kept "in step." . . . Hamilton Standard also announced a method of "armor coating" propeller blades with a thin layer of nickel to protect them against damage from stones, debris,



SOMETHING FOR A REAL SHARP PENCIL

A sharp pencil is one of the basic tools of the engineer, but the prime ingredient behind the pencil is a real sharp mind.

For this type of engineer, Bell has something more than just a job to offer . . . a rich rewarding career, with continued advancement, and exciting assignments demanding creative ability in a wide range of categories.

If you are interested in working on some of the most advanced projects in the industry, here is your opportunity to put a sharp pencil to good use.

BELL Aircraft CORPORATION

P. O. Box 1 Buffalo 5, N. Y.

Contact: Manager of Engineering Personnel 7 (B)

and water spray. This development has proved its worth as a major means of reducing propeller maintenance costs in 2,500,000 hours of commercial and military operation, the company said.

• **Westinghouse Electric Corporation,** Pittsburgh, has issued a 31-page booklet describing the engineering and manufacturing facilities available at its plant in Sunnyvale, Calif.

IAS SECTIONS

Meet Your Section Chairman

Karl Arnstein

Cleveland-Akron Section

In more than 31 years with Goodyear Aircraft Corporation, Karl Arnstein has had a hand in engineering large, rigid airships, manned stratosphere balloons, pressure-type airships for U.S. Navy patrol and antisubmarine warfare, military and personal airplanes, pilotless aircraft, and electronic devices.

Coming to the United States from Friedrichshafen, Germany, where he was Chief of Design for Luftschiffbau Zeppelin Company, he joined Goodyear Zeppelin in 1924 as Vice-President in charge of Engineering and has continued in the same capacity in Goodyear Aircraft from 1940 until the present.

Dr. Arnstein was educated at the Carlo-Ferdinand University and at Technische Hochschule in Prague, Czechoslovakia, where he received his professional engineer's diploma in 1910 and his degree as Doctor of Technical Sciences in 1912. After a few years of academic and practical work in bridge engineering, participating successfully in numerous design competitions for large span bridges and constructing one of them in Switzerland, he specialized in the theory, design, and construction of aircraft, particularly airships. He carried design responsibility on a great many Zeppelin prototypes, including the American airship "Los Angeles," which was built in Germany shortly after World War I under a reparations agreement. For his contributions to the theory and design of airships, he was awarded the honorary degree of Doctor of Engineering in 1926 by the Technische Hochschule of Aachen, Germany.

A Fellow of the Institute of the Aeronautical Sciences and the American Society of Mechanical Engineers, Dr. Arnstein has served on the NACA Subcommittee on Airships for about 10 years. In 1949 he was Vice-President of the Society of Automotive Engineers for Aircraft Activities. He is the author or coauthor of various books in the field of applied mechanics and has written a great number of papers related to aircraft and other lightweight structures.

Dr. Arnstein and his wife, Bertha, live in West Akron. They have a married daughter and two sons, both graduates of Harvard Medical School and now in residence at Massachusetts General Hospital in Boston. The Arnsteins take particular pride in their rose garden, which is one of the points visited on the Akron Art Institute's annual garden tour.

Argonne Lab

Chicago Section

Seventy-five members and guests of the Chicago Section visited the Argonne National Laboratory of the Atomic Energy Commission on October 5.

After dinner in the cafeteria, Chairman Pocock turned the meeting over to Ray Brittan who was responsible for arranging the tour. Three films showed construction details of the research reactor, reactor experiments at the National Reactor Testing Station in Idaho, and the first commercial lighting of a city by nuclear power.

The group, divided into several smaller units, then toured the reactor building. The new reactor using enriched uranium for fuel and cooled and moderated by heavy water received first attention.

The core of the reactor is 2 ft. in diameter and 2 ft. high and is composed of 17 fuel assemblies located in the center of an aluminum tank 6 ft. in diameter. This tank is filled with heavy water to a depth of $6\frac{1}{2}$ ft. during operation, which represents over 7 tons of heavy water.

A 2-ft. thick zone of graphite blocks surrounding the tank serves to reflect and moderate neutrons escaping from the heavy water. Outside the graphite, the neutrons and gamma rays are absorbed in a massive shield which constitutes most of the bulk and weight of the reactor. A steel tank lined with boron carbide surrounds the graphite and is in turn encased in concrete $4\frac{1}{2}$ ft. thick. Iron ore mixed in the concrete increases its density and, accordingly, its ability to stop radiation.

The fuel assemblies, in the form of thin plates to allow maximum contact with cooling water, are supported in thin-walled aluminum boxes somewhat resembling organ pipes. Heavy water is pumped up from below, through the fuel assemblies, and out into the main body of the tank near the top. In the basement is a heat exchanger which aids in transferring the heat to light water. In turn, the light water is cooled by flow through an outdoor cooling tower.

Four control rods, resembling railroad signal arms, operate between the parallel rows of fuel assemblies. Since, in case of emergency, they are automatically rotated rapidly to the lowered position in which they have maximum opportunity to absorb neutrons, they serve both as safety and control rods. A fifth unit, known as the regulating rod, moves up and down a short distance outside the fuel assemblies and serves for fine control.

The reactor has a negative temperature coefficient of reactivity; the rate of production of neutrons can be increased by lowering the temperature. Advantage is taken of this fact in making it possible to start up again shortly after shutdown.

Any impurity in the pile construction, especially any good neutron absorber, tends to lower the reproduction factor. Xenon, one of the fission products, has a very high cross section for absorption, hence it is an extremely efficient poison. Shortly after shutdown, the radioactive decay of other fission products produces a concentration of xenon such that the reactor could not normally be started again until the xenon had decayed in its turn. By cooling the heavy water with refrigerated water, however, the neutron efficiency can be built up. Continued operation then destroys the xenon, and the operation can be switched over to the normal temperature range.

The tour also included the control and operations room for this reactor.

A demonstration of 3-D color television was presented in connection with the operation of new electronic manipulators to be used as a remote mechanical handling setup. Members were

Hugh L. Dryden *(center)*, Director of the National Advisory Committee for Aeronautics, chats with Henry J. E. Reid *(left)* and Chairman Albert L. Braslow before addressing the Hampton Roads Section at a dinner meeting January 13.

permitted to demonstrate their proficiency in operating the system.

HARRY WIANT, *Secretary*

Hagerstown Section

Sixty-four members and guests attended a panel discussion on "Boundary-Layer Control" at the January 17 meeting. Robert A. Darby, Chief Research Engineer of Fairchild Aircraft Division, outlined the subject and served as moderator. The panelists were John S. Attinello, H. B. Helmbold, S. Lipson, W. C. Marlow, and F. G. Wagner.

The discussion covered objectives and general methods of achieving boundary-layer control, typical applications, system equipment and components, forced circulation, and probable future developments. Slides and films showed wind-tunnel tests of models and flight tests of aircraft incorporating boundary-layer control.

C. L. CHUMLEY
Secretary-Treasurer

Turbulence

Hampton Roads Section

Hugh L. Dryden, Director of the National Advisory Committee for Aeronautics and an Honorary Fellow of the IAS, spoke at the winter dinner meeting held on January 13. Ninety-nine members and guests attended.

Illustrating his subject with slides, Dr. Dryden discussed "The Origin of Turbulence in Fluid Motion." He was introduced by Henry J. E. Reid, Director of Langley Aeronautical Laboratory.

In tracing the development of the theory on the subject, Dr. Dryden mentioned the early work of Helmholtz, Prandtl, and Taylor, and the later developments of Tollmien, Schlicting, Theodorsen, and Emmons. Much of this work was concerned with boundary-layer transition.

It has been established that the flow in a boundary layer is extremely sensitive to minute disturbances. These disturbances appear as waves, periodic in nature, the frequency of which varies with the amplitude of oscillation. Tollmien and Schlicting computed the stability of such a disturbance in the boundary layer, and this theory was confirmed about 1940 by means of wind-tunnel tests.

It was later suggested by Emmons that boundary-layer transition takes place through the formation and growth of turbulent spots within the boundary layer, and this concept has recently been confirmed by Schubauer and Klebanoff of the National Bureau of Standards. The formation of turbulence appears to take place in three distinct steps: (1) an oscillation of the boundary layer which grows in amplitude, (2) the origin of spots of turbulence, and (3) growth of the turbulent spots.

The mechanism of the growth of turbulence begins as a two-dimensional wave, the amplitude of which varies periodically and which eventually assumes a three-dimensional character. As the wave velocity decreases, secondary wave disturbances develop, superimposed on the primary wave, and finally cause the flow stability to break down. There is no question that turbulence originates as a very localized three-dimensional disturbance; however, two-dimensional boundary-layer theory has not yet been expanded to embrace the three-dimensional aspects of the phenomena.

In his introductory remarks, Dr. Reid pointed out that the 1955 winners of both the Wright Brothers Memorial Trophy and the Collier Trophy—Dr. Dryden and Richard T. Whitcomb, respectively—were present at the meeting. Chairman Albert L. Braslow presided. Both the program and dinner were arranged by Laurence K. Loftin, Jr.

LEWIS R. FISHER
Recording Secretary

Los Angeles Section

The Wright Brothers Lecture for 1955 was delivered by Professor R. L. Bisplinghoff to the Los Angeles Section on December 20. His paper was entitled "Some Structural and Aeroelastic Considerations of High-Speed Flight."

George Mellinger, Section Chairman, opened the meeting to a large audience at 8:00 p.m. He introduced the Guest Chairman, Clark B. Millikan, Director of the Guggenheim Aeronautical Laboratory of the California Institute of Technology. Dr. Millikan's introduction noted that a massive field of scientific inquiry such as that encompassed by aerothermoelasticity required a compartmentalization and direction of inquiry within each field before a coordinated success could be achieved in detailed solutions. Dr. Bisplinghoff's work has established just this basis by setting up the structure required and giving direction within the branches of this field.

Prepared comments by C. H. Stevenson, Chief of Strength and Weights of the El Segundo Division of Douglas, Jerome F. McBrearty, Chief Structural Engineer of the California Division of Lockheed, and Y. C. Fung, Professor of Aeronautics at the California Institute of Technology, all agreed that the treatment of the subject was comprehensive and monumental and that the engineer and scientist in this branch of our industry will be both inspired and guided far along the aerothermoelastic road.

R. G. FULLER, *Secretary*

▸ At a recent specialist meeting, John Seddon of the Royal Aircraft Establishment discussed "Air Inlets with External Boundary Layers." He noted that at supersonic speeds the pressure recovery in normal shock inlets was much lower than that predicted by shock and friction losses. Transonic test data, together with Gedd's turbulent boundary-layer pressure rise equations and Lighthill's turbulent separation equa-

Sargent

hydraulic, pneumatic and mechanical aircraft controls

1 Valve Assembly — Steering Metering

2 Main Landing Gear Retractor

3 Brake Valves

4 Power control units for rudder, elevators and flaperons

5 Slat Actuating Cylinder

6 Gear Box Assembly — Outer Wing Flap Drive

7 Pneumatic Door Lock

8 Spoiler Valve

9 Accessory Drive Power Take-off

provide precision performance

For more than 35 years Sargent Engineering Corporation has designed and manufactured precision equipment.

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tions, led to a relation between separation point position and mass flow through the inlet. The incremental reductions in pressure recoveries were attributed to mixing losses which, subsequent to separation, could be virtually eliminated by boundary-layer vents just downstream of the separation point.

E. LAPIN
Meeting Coordinator

Wind Tunnels

St. Louis Section

The January 25 meeting brought to the Section members a presentation of wind-tunnel facilities and activities through a well prepared two-part program which included six men actively identified with research and development organizations. The first part, "Wind-Tunnel Operations at Tullahoma," was presented by Jack Shea, Special Assistant to the Director of ARO, Inc. The second part was a panel discussion entitled "Wind-Tunnel Techniques Employed in Development of High-Speed Aircraft."

The character and extent of the facilities of the Arnold Engineering Development Center were presented by motion pictures and slides with an accompanying discourse by Mr. Shea. AEDC developed from the realization of the need for a high-altitude, high-speed research center which became apparent at the end of World War II and was stimulated by the findings of aeronautical scientists who had evaluated German research facilities at that time. The estimated expense of construction and operation of an adequate facility indicated that Government ownership with industry-wide access was the only feasible arrangement. The site near Tullahoma, Tenn., was selected because of the availability of ample electric power and cooling water. In addition to ARO, Inc., the AEDC operating contractor, the total facility program includes construction supervision by the Tullahoma District of the U.S. Army Corps of Engineers and engineering design by Sverdrup and Parcel, Inc., of St. Louis.

In describing the three laboratories—the engine test facility, the propulsion wind tunnel, and the gas dynamics facility—Mr. Shea brought out some interesting information concerning the AEDC operation. In the production of test data, speed and accuracy are considered paramount. Automatic, on-line-data reduction of pressures, temperatures, and forces from analog to digital signals, using Remington-Rand Univac equipment, has made it possible for engineers to have test data ready for incorporation in reports within 20 sec. This speed has the additional advantage of making it possible to spot data immediately which appears to be out of line and of conducting reruns with minimum cost and delay.

Other instances illustrating overall savings in time and expense were given. In a missile propulsion system development, valid test conditions at 83,000 ft. were reached with a loss of two engines, whereas an estimated 60 firings would have been required for the same results without access to the AEDC laboratory facilities. In the engine test cell, the variable nozzle makes it possible, in a single test, to simulate climb, level flight, and descent, and to change Mach Numbers as desired. In another case, an engine failure in the cell yielded information that explained the cause of 18 actual airplane crashes.

A short description was given of the porous walls and plenum chamber evacuation used in transonic wind-tunnel work for the elimination of shock-wave interference.

The panel discussion was presented by the moderator, William J. Blatz, Project Development Engineer, McDonnell Aircraft; and members Robert Belt, Chief of Wind-Tunnel Testing, McDonnell Aircraft; Hugh Gardenier, Project Manager, Transonic Branch, AEDC; William Rivers, Project Engineer, Wind-Tunnel Design, Sverdrup & Parcel; and Demetrius Zonars, Chief, 10-Ft. Transonic Wind Tunnel, WADC.

Mr. Blatz reviewed present high-speed wind-tunnel sponsorship and management, classifying the tunnels into privately owned-privately managed, Government owned-Government managed, and Government owned-contractor managed. His introduction of the panel members included a résumé of the activity in which each is engaged.

Mr. Belt explained in detail the purpose of a company-owned wind tunnel in development work. Mr. Zonars outlined the uses made of the six different wind tunnels at WADC. Mr. Gardenier reviewed the problems encountered in developing aerodynamic research facilities, indicating dependence on the state of measuring equipment evolution. Mr. Rivers explained the extent of high-speed wind-tunnel usage today; he enumerated the tunnels at military and NACA establishments for research and development and the industry-owned and operated tunnels at Caltech, Cornell, United Aircraft, Boeing, M.I.T., North American, Douglas, Convair, and Martin and identified them as supersonic, transonic, trisonic or bisonic.

Mr. Blatz elaborated on the cost of basic-research testing and development testing and solicited comment from the panel members on the relative economics of a large number of elementary tunnels in preference to a single elaborately equipped tunnel. It was brought out that, as high-speed design progresses in the years ahead, there will be an increasing amount of wind-tunnel testing required, taxing all facilities to the limit. Mr. Gardenier recommended maximum utilization of the elaborately equipped tunnel as representing a possible solution. Mr. Zonars said that the present and normal backlogs at WADC restricted all work for the next 2 years to development work, with research opportunities possible only at some future date. In defense of the need for immediate information in development work, Mr. Rivers cited the power economies of company-owned tunnels which use stored energy for short periods of high-speed testing. This work, handled locally, in turn releases other facilities for research work. Mr. Belt felt that company-owned tunnels eliminated many demands on research tunnels, with the possibility that more unhampered advanced research might produce information earlier and even reduce the areas of conjecture responsible for the development testing. Company tunnels, he thought, needed digitizing recorder systems to replace the manual systems in the drive for increased utilization.

These panel discussions were followed by questions from the floor concerning accuracy of data, tunnel demands, and tunnel construction. About 150 attended the meeting.

FREDERICK H. ROEVER
Recording Secretary

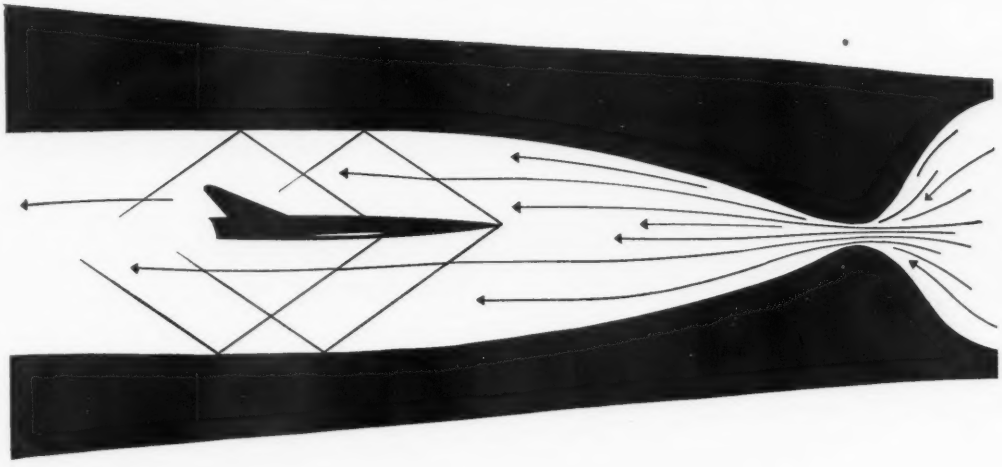
San Diego Section

"The Trend in Weapons Systems over the Next 20 Years" was the subject of an address at the January 12 dinner meeting by T. G. Lanphier, Jr., of Convair, A Division of General Dynamics Corporation. Mr. Lanphier, a former Air Force fighter pilot, is Vice-President for Long-Range Planning and Assistant to the President of Convair.

The speaker emphasized the inability of present defensive systems to protect us from present offensive systems. He pointed out that this has been generally true in the past and that there is no reason to believe that it will not be true in the future. Because of this, military strength must be measured in terms of offensive capacity. The long-term periods required for development of an idea into an effective weapons system was cited, and the B-47, B-52, and B-58 systems were used as examples.

These long development periods are being eliminated in Russia through the use of rigid controls and an abundance of manpower. Mr. Lanphier feels that, because of this, we are rapidly losing our position of supremacy and the freedom

Guided Missile Engineers and Scientists



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of our country is seriously threatened. It was pointed out that the decline of our position of supremacy can be halted or reversed if the people of the United States are made aware of the decline and of the danger inherent in this loss of supremacy. Mr. Lanphier emphasized that an all-out effort must be made at a high level for us to regain our position in the world; and when we do have a position of military supremacy it must be used to back up a positive political offensive.

▶ James L. Edman, Chief of Technical Systems Analysis for Bendix Aviation Corporation, presented a paper on "The Dynamics of Landing Gear Systems" at the technical meeting on January 20. His discussion covered three main topics—metering-pin design, wheel-and-strut chatter and squeal, and nose-wheel shimmy. He indicated the methods of analysis used by Bendix in all of these studies. Slides were shown of the various testing facilities used by Bendix to verify their analysis procedures.

R. A. FUHRMAN
Corresponding Secretary

Wichita Section

Colonel William B. Bunker, USA, President of the American Helicopter Society, spoke on "The Individual Lift Device" at a joint meeting of AHS-SAE-IAS on January 18.

A long-time proponent of the helicopter for military use, Colonel Bunker gave a comprehensive review of the history of the individual lift device concept followed by his views on the potentialities of such craft in the Army. Illustrating his talk with sketches, he described various types of one-man flying machines and called attention to their limitations.

SANFORD H. HINTON, *Secretary*

STUDENT BRANCHES

California State Polytechnic College

Seventy-five students attended the February 2 meeting to hear Frank D. Mathes, Jr., Manager of Custom Field Service for Northrop Aircraft, Inc., speak on "Cold-Weather Operations of Northrop's F-89 Scorpion."

Mr. Mathes outlined the maintenance problems of the all-weather interceptor and the need for clean, logical design in all aircraft. He then introduced a 1952 Cal Poly graduate, Walter Kolar, Jr., who is now a Northrop Technical Representative. Supplementing the speaker's comments on maintenance, Mr. Kolar related his own experiences as Team Head and Senior Tech Rep at Ladd Air Force Base in Fairbanks, Alaska.

ELMER J. BISHOP, *Reporter*

The Catholic University of America

Chairman Nicholas Gallipoli introduced Comdr. Edward T. LeRoe, USN, as the speaker at the December 15 meeting. Commander LeRoe, who is attached to the Bureau of Aeronautics, described its purpose and organizational structure within the Department of the Navy.

▶ The November 22 meeting was devoted to two motion pictures, *New Wings for the Navy* and *PBM-3 Wing Destruction Tests.*

JAMES R. MCGRATH, *Secretary*

Georgia Institute of Technology

Twenty-six members heard a talk by Robert S. Chubb, Operations Research Specialist of the Georgia Division of Lockheed Aircraft Corporation, at the January 23 meeting.

Mr. Chubb spoke about "Aerodynamics." His talk was based on the three S's: Subsonic, Supersonic, and Spiritual. The subsonic portion consisted of the basic principles of dynamic flight, displacement, lift, drag, circulation theory, and two- and three-dimensional theory. In supersonics, he explained buffeting, tucking, shock waves, and other basic theory, including the new "area rule." In dealing with the spiritual, Mr. Chubb closed with a quotation from Proverbs, beginning:

"There be three things which are too wonderful for me, yea, four which I know not: The way of an eagle in the air. . . ."

▶ Fifty-eight members attended the January 9 meeting. John J. Harper, Faculty Adviser, announced that a Regional Student Paper Competition would be held in April at the University of Alabama. He urged the students to enter their technical papers.

Bob Russ discussed Engineers' Week. Chairman Roland Fuentes appointed a committee to arrange an IAS party for March 3. The meeting closed with the showing of two films, *YF-100A* and *Range Unlimited.*

ROBERT E. DROWNS, *Secretary*

Illinois Institute of Technology

Seventy students attended the October meeting to hear a talk on "Parachute Development" by Harold V. Hawkins, AFIAS, Assistant Director of Cook Research Laboratories. He exhibited several types of parachutes. The lecture was followed by a Cook Laboratories motion picture describing research on parachutes.

MERRILL J. FOOTE, *Secretary*

Iowa State College

A British motion picture, *Powered Flight,* was shown at the February 1 meeting. Placing special emphasis on the part played by British aircraft in aeronautical history, it closed with scenes of the de Havilland Comet.

▶ Arnold Anderson of the Aeronautical Engineering Department gave a talk on the Navy's David Taylor Model Basin near Carderock, Md., at the January 18 meeting. A movie showing the facilities of the model basin and the type of work done there was shown before Professor Anderson began his talk. He explained the function, in the Naval development system, of the model basin, with which he was associated before coming to Ames in September, 1955. Professor Anderson told about some of the projects he had worked on and some of the difficulties he had met. He specifically described the problems that had been encountered while testing a model of a large helicopter in the model basin's wind tunnel.

ROBERT D. DIGHTON, *Secretary*

Kansas State College

P. G. Kirmser of the Applied Mechanics Department spoke January 19 on the "Bikini Able Baker A-Bomb Tests." Professor Kirmser formerly was a Naval Officer assigned to duty as a physicist in connection with these tests. He discussed methods of measuring the blast effects and related some of his own experiences. These comments were illustrated with still pictures from news reports and books. His comments were followed by the presentation of a short film on the same subject selected from the file of the Olathe NAS by Bob Miller, Program Chairman.

Preliminary plans for IAS participation in the Engineer's Open House were discussed by Craig Birtell, Open House Chairman of the Student Branch.

ELMER R. NELSON, *Secretary*

Northrop Aeronautical Institute

The subject of the January meeting was a talk on analog computers by Kenneth E. Heist of the Technical

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right: engineers and scientists work on some the 46 major projects in progress at Lockheed

Operations Research discussion on continental defense

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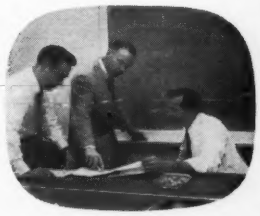

Aerodynamic meeting on high-speed fighter

Aerodynamics openings

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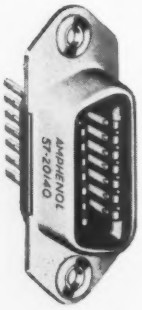
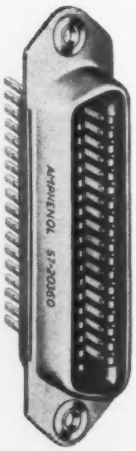


14 contacts

illustrated actual size

36 contacts



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Mr. Heist began by comparing analog with digital computers and citing several examples of each type. He then explained the function of the various components of a typical large analog machine in solving differential equations. As an example of its value to the aeronautical engineer, Mr. Heist showed how the analog computer might be used in developing an automatic pilot, both in preliminary design stage and in evaluation of the manufactured product. In conclusion, he emphasized the computer's ability to record several functions in graphic form for study.

GARLAND O. GOODWIN
Vice-Chairman

Polytechnic Institute of Brooklyn

George W. Benedict, of North American Aviation, Inc., spoke at the January 5 meeting on opportunities available in the aviation industry. Sketching the growth of the aviation industry, he said 750,000 persons are employed in it today. There are problems in many fields which need to be explored, creating a demand for large numbers of engineers. North American Aviation has 13,000 engineers among its 62,000 employees.

Rocket propulsion and electronics are playing an increasingly important role, he pointed out. In modern airplanes, there are over 4 miles of wiring. Missiles are taking a large share of the defense budget. High temperatures create the necessity of developing metals to withstand heat up to 7,000°F. In contrast, aluminum loses 40 per cent of its strength at 250°F. Techniques of manufacture must also be studied. The application of coin dimpling to the Sabre added 10 m.p.h. to its speed.

The talk was followed by a film on rocket propulsion developments at North American Aviation.

▶ On December 14, Lawrence Kaufman of the Sperry Gyroscope Company delivered a talk entitled "Helicopter Flight Control." Mr. Kaufman traced the history of the helicopter from the earliest beginnings of the idea in the time of Archimedes to the present. The chief problem with present-day helicopters, he said, is their lack of stability, which is most pronounced in pitch and roll. In addition to this, the helicopter requires five independent controls, some of which must be moved three to four times per second. There are two types of solution to the problem of instability—a mechanical or aerodynamic mechanism and some form of automatic control such as the autopilot. The remainder of the talk was devoted to the autopilot.

All autopilots should be operated from the basic controls, since many

pilots would be reluctant to use the automatic pilot if it were not attached to them. The autopilot system consists of the following parts: the senser, which measures the helicopter's attitude; the pilot command facility, which sets up the desired helicopter attitude; the computer, which tells the servomechanism how to move to get the desired attitude; the amplifier; and, finally, the servomechanism itself, which changes the helicopter attitude. Mr. Kaufman also discussed the necessity for developing failureproof components and the sequence in which a product was developed. Slides were used to illustrate his comments.

HOWARD BAUM
Recording Secretary

Purdue University

The following officers have been elected for the spring semester: L. Rittenhouse, Chairman; J. D. Morton, Jr., Vice-Chairman; D. D. Hofferth, Secretary; and A. W. Stabler, Treasurer. W. D. Hayden was appointed Program Chairman and W. R. Long, Publicity Chairman. P. E. Stanley and M. I. Fowler were chosen as Faculty Advisers.

The election on January 17 was followed by a motion picture, *Arnold Engineering Development Center Briefing Film*, describing new test facilities at Tullahoma, Tenn. W. R. Long, a student member, then showed two films he had made at the National Aircraft Shows of 1953 and 1954.

DELBERT D. HOFFERTH, *Secretary*

University of Alabama

The following officers have been elected for the spring semester: Karl O. Ball, Vice-Chairman; J. O. Nichols, Secretary; and J. Herring, Treasurer. Election of a Chairman was postponed.

Plans for the 'Bama Educational Festival and for a joint meeting with other engineering societies were discussed at the January 12 meeting. Edward W. Geller, Faculty Adviser, announced that the Student Branch had received an invitation to visit Redstone Arsenal, Huntsville, Ala. The meeting closed with a film on the Lockheed P-38.

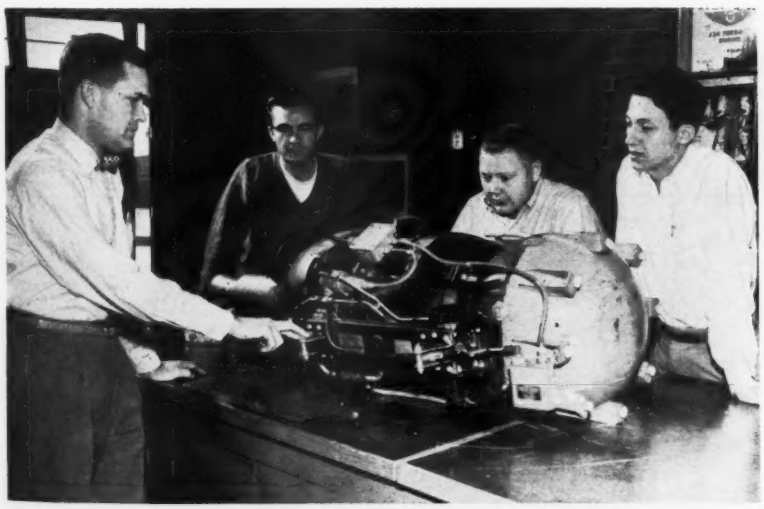
▶ Our December 3 meeting was held in Starkville, Miss., with the Student Branch of Mississippi State College as host. J. J. Cornish, of the Department of Aerophysics at Mississippi State, spoke on "The Theory of Boundary-Layer Control by Suction."

The visitors from Alabama toured the Aerophysics Department's facilities. There was a flight demonstration of an airplane utilizing boundary-layer control by suction to reduce its stalling speed. The plane was piloted by T. Moore, a member of our Student Branch.

▶ Fifty-five students attended the November 17 meeting. Colgan H. Bryan, Head of the Department of Aeronautical Engineering, outlined plans for Regional Student conferences to be held in April at Dallas, Tex., and here in Atlanta. The members voted to accept the invitation from the Texas Section and to select two papers to be presented in person by their authors.

S. Walter Hixon, Jr., Director of Training at Langley Aeronautical Laboratory, National Advisory Committee for Aeronautics, described the various types of research conducted at Langley Field, Va., and mentioned some outstanding contributions to aviation that originated there. He told of a Government-sponsored training program for graduate students employed by NACA as Aeronautical Research Scientists. An NACA movie was shown.

KARL O. BALL, *Secretary*



Three members of the IAS Student Branch at the University of Oklahoma study a rocket engine in the Propulsion Laboratory. *Left to right:* Prof. B. V. Ketcham, Ralph Capshaw, Thomas Shoebotham, and Warren Adam.

University of Kentucky

Karl O. Lange, Faculty Adviser of this new Student Branch, spoke at the January meeting on the advantages of membership in the Institute of the Aeronautical Sciences. Wendell Norman, Program Chairman, discussed the Institute's two magazines, the AERONAUTICAL ENGINEERING REVIEW and the JOURNAL OF THE AERONAUTICAL SCIENCES.

Fourteen new members were enrolled at this meeting. Leonard Bennett was appointed Program Chairman, succeeding Mr. Norman.

WALTER J. BLACKSON, *Secretary*

University of Michigan

Peter Audano, a Senior Group Engineer in the Fort Worth plant of Convair, A Division of General Dynamics Corporation, spoke at the January 10 meeting. He was introduced by Chairman Robert Lauer.

Describing the work and status of "The Aeronautical Engineer in Industry Today," Mr. Audano called attention to the many problems that must be solved by the aeronautical engineer in aerodynamics, structures, propulsion, and related fields.

ROBERT R. JONES, *Secretary*

University of Notre Dame

Thomas Mahoney was elected to the IAS Engineering Advisory Board at the January 30 meeting.

▶ At the December 2 meeting, Chairman Joseph P. Poynton welcomed one of Notre Dame's successful engineering graduates, Robert S. Kraemer, TMIAS, Supervisor of Preliminary Analysis at the Propulsion Center of North American Aviation, Inc., Los Angeles. Mr. Kraemer described his experiences as a young engineer on his first job and gave some helpful hints on what to expect in industry. After a discussion of rocket engine design and testing, a color sound film was shown describing North American's rocket-sled tests to determine the strength of various parachute fabrics. Seventy-five students were present.

RAYMOND J. MAUREN, *Secretary*

University of Oklahoma

B. J. Simmons of the Autonetics Group, North American Aviation, Inc., spoke on "Inertial Navigation" at our

January 31 meeting. This is a new method of navigation for guided missiles and supersonic aircraft. Forty-two members and guests were present.

Emmett Fry was elected Chairman and Larry Mozier, Vice-Chairman for the spring semester.

Following a discussion about the Engineers' Open House, the Student Branch decided to appropriate $75 to complete a full-size airplane being built by two of our members from plans in *Mechanix Illustrated*. The plane will be exhibited at the Open House in March.

THOMAS B. SHOEBOTHAM, *Secretary*

▶ Seniors were interviewed at the December 13 meeting by two personnel representatives of the Tulsa Division of Douglas Aircraft Company, Inc. One of the visitors, Jim Kelm, a Stress Engineer, was an O.U. graduate. A trip to the Douglas plant may be arranged for members of the IAS Student Branch.

▶ Sixty members and guests attended the December 6 meeting at which a group photo was made for the college yearbook, the *Sooner*. Two films of exceptional interest were shown—one on the Boeing KC-135 Stratotanker and the other on the Northrop Flying Wing.

Faculty Adviser L. A. Comp discussed the annual Southwestern Student Paper Competition to be held in Fort Worth in April. The members voted unanimously to accept the Texas Section's invitation to be represented.

PHIL FISHER, *Chairman*

University of Southern California

Welko E. Gasich, MIAS, spoke on "General Preliminary Design Problems" at the November 28 meeting. Mr. Gasich, who is Chief of Preliminary Design at Northrop Aircraft, Inc., outlined some of the outstanding design problems of the aircraft industry.

▶ "The best field trip we ever attended" took place November 16 when 20 student members visited the NACA's High-Speed Flight Station at Edwards AFB, Calif. After introductory talks by three NACA engineers, most of the experimental aircraft and the instrumentation used for recording test data were inspected.

▶ Walter Powell of the Jet Propulsion Laboratory at Caltech spoke at the noon meeting on November 14. His subject was "Problems and Goals in Rocket Propulsion." Three of the principal problems encountered in rocket design, he said, are heat transfer, selection of proper metals, and determination of high-stress-concentration areas. The lecture was illustrated with slides showing rockets designed and tested at Caltech.

GILBERT HERRERA, *Secretary*

University of Utah

Lieutenant Marvin J. Tobias, USAF, a senior engineering student and a pilot in the Utah Air National Guard, spoke at the January meeting on "Problems Confronting a Jet Pilot."

He described flight characteristics of jet airplanes in general, explaining how most of these characteristics were advantageous to the "flying gun platform" and how some created problems for the pilot.

Of special interest was the concern for pilot safety and comfort exemplified by pressurized cockpits, oxygen systems, cooling and heating, G-suits, and emergency procedures and tactics.

A Lockheed film, *Aeroelasticity of Supersonic Wings*, was shown after the talk. It was agreed that more senior engineers should be invited to speak at the IAS meetings.

SAL TRIPOLI, *Secretary*

Virginia Polytechnic Institute

A motion picture, *Higher and Faster*, was shown at the January 24 meeting. It covered the design, construction, and testing of the Republic F-84 fighter-bomber.

The Student Branch discussed plans for the Engineering Conference to be held here April 27 and 28 and for the IAS Regional Student Conference in Atlanta.

GEORGE E. POWELL, *Secretary*

West Virginia University

Two color films were shown at the January 4 meeting. *The Intruders* emphasized the difficulty of convincing the public that jet-engine noise is a necessary evil, not a vicious plot against Mr. Average Citizen. *Horizons Unlimited* showed the assembly, testing, and firing of Viking rockets at White Sands Proving Ground, N. M. This film included shots of the earth made from extremely high altitudes.

The Engineers' Ball was held in January.

Spin Tunnel

▶ A talk on the National Advisory Committee for Aeronautics brightened the December 7 meeting. The speaker was A. I. Neihouse, Head of the Spin Tunnel Section of Langley Aeronautical Laboratory, NACA, Langley Field, Va.

Listing some of the wind tunnels and other laboratory facilities of the NACA, Mr. Neihouse touched on the aerodynamics work done at Langley, jet engine research at Lewis Flight Propulsion Laboratory in Cleveland, and supersonic research at Ames Aeronautical Laboratory at Moffett Field, Calif. He described his own work in the Spin Tunnel, which was one of the NACA's first wind tunnels and which has furnished test data on stability and control that has proved vital to the design of every modern American airplane. Dynamic scale models of fighters, particularly, are flown in the Spin Tunnel before the prototype is constructed.

The importance of the study of spin characteristics (despite lack of publicity, Mr. Neihouse remarked) was brought home forcibly by several striking examples. For instance, many MiG-15 kills were scored in Korea because the Russian-built fighter had poor spin recovery, while there is no record of an American F-86 spinning in.

The speaker showed a film describing how the small flying models used in the Spin Tunnel are constructed and how they are tested to demonstrate the inherent spin-recovery characteristics of the airplanes they represent.

RAY HERRING
Corresponding Secretary

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Baker, W. R. G., Dr. Engr., V-P—Electronics Div., General Electric Co. (Syracuse).

Bauer, Chester R., B.S. in Ae.E., Aerodynamics Engr., Douglas Aircraft Co., Inc. (Long Beach).

Dietz, Robert O., B.S.M.E., Chief of Staff—Engrg. & Asst. Chief—Engine Test Facility, ARO, Inc.

Herrmann, Werner E., Flight Test Analysis Engr. "A," Flight Test Electronics Dept., Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Hills, Ronald, B.A., Chief Executive, Aircraft Research Assn. (England).

Keen, Edward D., B.Sc. (Engrg.), Chief Designer, Sir W. G. Armstrong Whitworth Aircraft Co., Ltd.

Pedersen, Arthur H., B.S. in C.E., Chief Test Engr., McDonnell Aircraft Corp.

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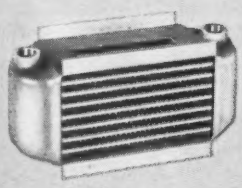

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Brannin, Richard S., B.S.E.E., Dir.—Research & Advanced Devel., Aero. Equipment Div., Sperry Gyroscope Co. Div., Sperry Rand Corp.

Britton, Sydney L., B.S. in Ae.E., Chief Proj. Engr., Orenda Engines, Ltd.

Corson, Blake W., Jr., B.S., Aero. Research Scientist, Section Head, NACA, Langley AFB.

Putt, Gladyn H., B.S., Research Admin., The RAND Corp.

Zahorski, Adam T., Ph.D., Chief, Struct. Div., Aerophysics Development Corp.

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Alexander, Ray B., Lab. Staff Armament Engr., McDonnell Aircraft Corp.

Allen, Warren L., B.S., Proj. Engr., Design Group, Allison Div., General Motors Corp.

Allmeroth, Henry G., Design Engr., East Coast Aeronautics, Inc.

Anderhub, Anthony P., B.S., Physical Test Engr., McDonnell Aircraft Corp.

Barry, Farris R., B.S., Design Engr., McDonnell Aircraft Corp.

Bellan, Theodore M., M.S. in M.E., Supvr.—Dept. of Applied Math., McDonnell Aircraft Corp.

Bernard, Margaret H., A.B., Group Leader, Aerodynamic Dept., McDonnell Aircraft Corp.

Bowman, Donald R., B.S. in M.E. (Aero.), Aerodynamicist, McDonnell Aircraft Corp.

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Brackin, Harl V., Jr., Engrg. Designer "B," Engrg. Dept., Boeing Airplane Co. (Seattle).

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Bruyette, Gerald W., B.M.E. (Aero.), Supvr.—Functional Evaluation, McDonnell Aircraft Corp.

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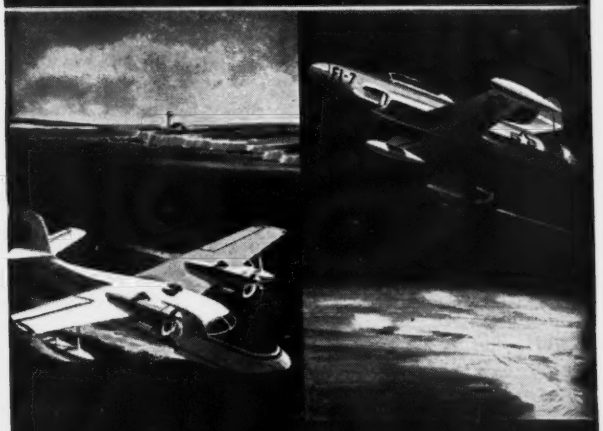

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Jalon, Manuel, Ing. Aeronautico, Capt. Ing. Aero., Jefe Del Escuadron De Mantenimiente De La Base Aerea Valensuela de Zaragoza, Ejercito Del Aire De Espana.

Jensen, Robert M., Aircraft Electrical Systems Engr., Aircraft Engrg. Div., Lear, Inc.

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Klockzien, Vincent H., B.S., Assoc. Engr., Flight & Mech. Lab., Douglas Aircraft Co., Inc. (Santa Monica).

Mabie, Edward L., B.S. in M.E., Layout Engr., McDonnell Aircraft Corp.

McElhiney, Robert S., B.S.M.E., Design Engr., McDonnell Aircraft Corp.

McKeon, James C., B.S., Detail Engr., Experimental Test—Jet & Turboprop Engines, Allison Div., General Motors Corp.

Niemeier, Herman R., B.S.C.E., Test Engr., Physical Test Lab., McDonnell Aircraft Corp.

Osborne, James T., B.S. in Physics, Weight Engr., Lockheed Aircraft Corp. (Marietta).

Page, Armand J., Liaison Engr., Landing Gear Group, Fairchild Aircraft Div., Fairchild Engine & Airplane Corp.

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Ferris, Edwin W., Jr., Instrumentation Engr., Grumman Aircraft Engineering Corp.

Fox, Kenneth L., B.S. in Aero., Design Engr., Class "B," McDonnell Aircraft Corp.

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Gayne, William J., Design Trainee, Grumman Aircraft Engineering Corp.

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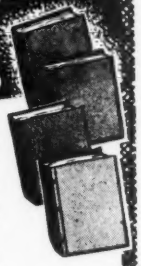

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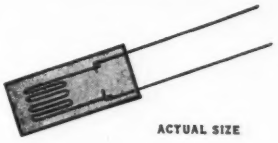

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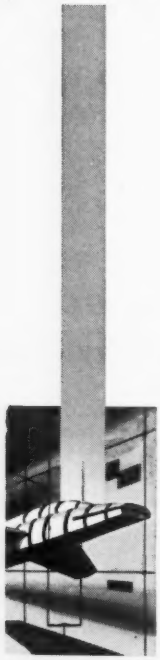

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PERIODICALS & REPORTS..... 156
INTERNATIONAL AERONAUTICAL ABSTRACTS. 169
BOOKS..... 189

Subject Index to Periodicals & Reports

Acoustics, Sound & Noise..... 156
Aerodynamics
  Boundary Layer & Thermoaerodynamics..... 156
  Control Surfaces..... 156
  Fluid Mechanics & Aerodynamic Theory..... 156
  Internal Flow..... 158
  Performance..... 158
  Stability & Control..... 158
  Wings & Airfoils..... 160
Aeroelasticity..... 160
Air Transportation..... 162
Airplane Design..... 162
  Body Group..... 162
  Control Systems..... 162
  Development Testing..... 162
Airports
  Traffic Control..... 162
Aviation Medicine..... 162
Computers..... 162
Education & Training..... 162
Electronics
  Amplifiers..... 162
  Circuits & Components..... 162
  Communications..... 163
  Cooling..... 163
  Dielectrics..... 163
  Electronic Controls..... 163
  Magnetic Devices..... 163
  Measurements & Testing..... 163
  Navigation Aids..... 164
  Oscillators & Signal Generators... 164
  Radar..... 164
  Semiconductors..... 164
  Transmission Lines..... 164
  Wave Propagation..... 164
Equipment..... 164
  Hydraulic & Pneumatic..... 164
Fuels & Lubricants..... 164
Ice Formation & Prevention..... 164
Instruments
  Flow Measuring Devices..... 164
  Gyroscopes..... 164
  Pressure Measuring Devices..... 164
  Temperature Measuring Devices... 165
Machine Elements
  Fastenings..... 165
  Rotating Discs & Shafts..... 165
  Springs..... 165
Materials
  Corrosion & Protective Coatings... 166
  Metals & Alloys..... 166
  Metals & Alloys, Nonferrous..... 166
  Nonmetallic Materials..... 166
  Testing..... 166
Mathematics..... 166
Meteorology..... 166
Missiles..... 166
Navigation..... 185
Photography..... 185
Power Plants
  Jet & Turbine..... 185
  Ram-Jet & Pulse-Jet..... 185
  Rocket..... 185
Production..... 185
  Metal Working..... 185
  Nonmetal Working..... 185
  Production Engineering..... 185
  Tooling..... 185
  Welding..... 185
Propellers..... 186
Rotating Wing Aircraft..... 186
Safety..... 187
Space Travel..... 187
Structures..... 187
  Bars & Rods..... 187
  Beams & Columns..... 187
  Connections..... 187
  Cylinders & Shells..... 187
  Elasticity & Plasticity..... 187
  Plates..... 188
  Testing..... 188
  Thermal Stress..... 188
Thermodynamics..... 188
  Heat Transfer..... 188
Vertical Take-Off Aircraft..... 188
Water-Borne Aircraft..... 188
Wind Tunnels & Research Facilities... 188

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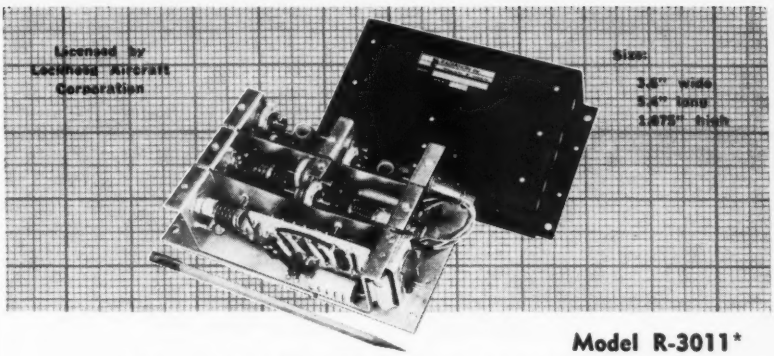

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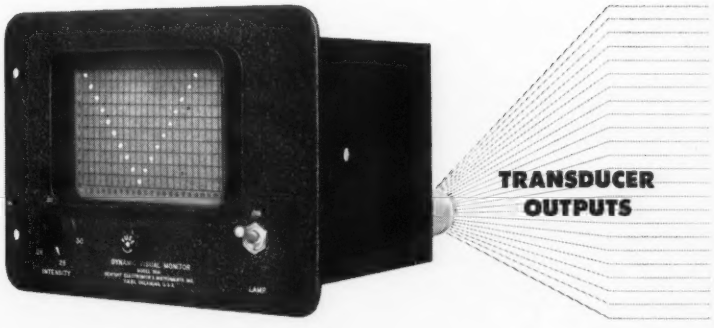

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PUBLISHED MONTHLY BY THE AERONAUTICAL ENGINEERING REVIEW
Official Publication of the Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N.Y.

Volume 1, Number 4 April, 1956

ACOUSTICS, SOUND, AND NOISE

ON THE AERODYNAMIC SURFACE SOUND FROM A PLANE TURBULENT BOUNDARY LAYER. O.M. Phillips. Proc. Royal Soc. (London), Ser. A, Feb. 21, 1956, pp. 327-335. Results of a theoretical investigation indicating that the dipole sound radiated per unit area vanishes as a consequence of the vanishing of the mean-square momentum per unit area of the shear layer when a turbulent fluid moves across an infinite flat plate with motion statistically homogeneous in planes parallel to the plate, but that a nonzero radiation field may be established when the motion in the parallel planes is not homogeneous, thus that a semi-infinite flat plate in a uniform stream produces a finite dipole radiation per unit area becoming vanishingly small with increasing distance down the plate.

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AERODYNAMICS

Boundary Layer and Thermoaerodynamics

CROSS FLOWS IN LAMINAR INCOMPRESSIBLE BOUNDARY LAYERS. Appendixes A, B - CALCULATION OF FUNCTIONS. Appendix C - RESOLUTION OF BOUNDARY-LAYER VELOCITIES INTO COMPONENTS NORMAL AND TANGENTIAL TO MAIN-FLOW STREAMLINES. A.G. Hansen and H.Z. Herzing. US, NACA TN 3651, Feb., 1956. 50 pp. Analytical derivation for three-dimensional laminar and incompressible boundary-layer flow over a flat surface with a leading edge under main-flow streamlines translated and represented by polynomial expressions, with the profiles of their velocity components having similarity with respect to rectangular coordinates. Includes tables of special functions of the Blasius similarity parameter required for computing boundary-layer cross flows; and experimental smoke flow-visualization results used to compare the behavior of thick and thin boundary layers.

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FORMULAE AND APPROXIMATIONS FOR AERODYNAMIC HEATING RATES IN HIGH SPEED FLIGHT. Appendix I - FACTORS INFLUENCING TRANSITION. R.J. Monaghan. Gt. Brit., RAE TN Aero. 2407, Oct., 1955. 53 pp. 19 refs. Derivation of formulas to estimate local and mean heat flow rates, with laminar or turbulent boundary layers related to transitional problems of laminar to turbulent flow, taking into account the effects of

Mach Number, surface temperature, altitude, and Reynolds Number on heat flow rates, and the effects of radiation and the time required for the skin to reach the resulting equilibrium at constant Mach Number and altitude. Analysis under the assumption of neglected longitudinal temperature and pressure gradients based on flat-plate theory to obtain rough approximations in terms of expected minimal effect of small pressure and temperature gradients on thin wings and slender bodies in supersonic flight.

HEAT TRANSFER CHARACTERISTICS OF A HEMISPHERE CYLINDER AT HYPERSONIC MACH NUMBERS. E.M. Winkler and J.E. Danberg. IAS 24th Annual Meeting, New York, Jan. 23--26, 1956, Preprint 622. 15 pp. Members, $0.50; nonmembers, $0.85. Results of the USAF-NAVORD-sponsored experimental investigation in the NOL Hypersonic Tunnel at Mach Numbers up to M = 8, free-stream Reynolds Numbers based on model diameter in the range from 70,000 to 400,000, and the wall to stagnation temperature ratios from 0.43 to 0.75, with data evaluated from temperature differences across the wall on a cooled model under steady state conditions. Results, reduced to local nondimensional heat-transfer parameters and compared to those predicted by the Korobkin modified incompressible theory, indicate peak values for angular positions of about 11 and 45 degrees and high values at the shoulder.

SOME EFFECTS OF BLUNTNESS ON BOUNDARY-LAYER TRANSITION AND HEAT TRANSFER AT SUPERSONIC SPEEDS. Appendixes A, B - DISSIPATION OF THE LOW MACH NUMBER LAYER. Appendix C - MACH NUMBER PROFILES PRODUCED BY DETACHED SHOCK WAVES. W.E. Moeckel. US, NACA TN 3653, Mar., 1956. 43 pp. 19 refs. Analysis of downstream transition movements in the presence of slightly blunted leading edges of hollow cylinders or flat plates at Mach Numbers up to 20, in terms of the reduction of Reynolds Numbers at the outer edge of the boundary layer due to the detached shock wave, based on the hypothesis of a substantially unchanged transition Reynolds Number when a sharp leading edge or tip is blunted. Results, as compared to experimental results for hollow tubes tested at Mach 3.1, indicate that the downstream movement of transition is inversely proportional to the ratio of surface Reynolds Number with blunted tip or leading edge to surface Reynolds Number with sharp tip or leading edge; that at other Mach Numbers, blunting the tip of slender cones or the leading edge of thin wedges should produce downstream movements by factors ranging from 2 at M = 3.0 to 30 at M = 15 as related to the possible reduction in over-all heat-transfer rate and friction drag for aircraft flying at high supersonic and hypersonic speeds.

Control Surfaces

A METHOD FOR PREDICTING LIFT EFFECTIVENESS OF SPOILERS AT SUBSONIC SPEEDS. A.L. Jones, Owen P. Lamb, and A.E. Cronk. J. Aero. Sci., Apr., 1956, pp. 330 - 334, 376. WADC-supported development of a rapid, straightforward estimation procedure applicable at Mach Numbers up to approximately 0.95 for an angle-of-attack range restricted to an upper limit of about 6 degrees for upper-surface control devices, taking into account the effects of the basic parameters of aspect and taper ratios, sweepback, airfoil thickness ratio, chordwise location and spanwise extent and location of any control, and using design charts to indicate the relative effects of variations in each parameter.

MIXING AND THE JET FLAP. Appendix I - THE MOMENTUM METHOD; AN ALTERNATIVE APPROACH TO THE MIXING BETWEEN THE JET AND THE MAIN STREAM. Appendix II - CONSIDERATIONS OF SINKS AND SOURCES IN ORDER TO VISUALIZE THE FLOW - FURTHER DETAILS. Appendix III - MIXING BETWEEN THE AEROFOIL BOUNDARY LAYERS AND THE JET - FURTHER DETAILS. B.S. Stratford and N.A. Dimmock. Gt. Brit., NGTE Memo. M.250, Oct., 1955. 45 pp. Results of theoretical and experimental investigations of the high lift technique indicating the possible reduction of thrust loss through the use of bypass engines and a shrouded jet flap at take-off, with a formulation of thrust augmentation off setting the primary effects of mixing, neglecting the importance of the jet low-density as a factor in cruising flight, the velocity component, energies and moments associated with it, and of the surrounding air perpendicular to and into the jet.

THE PRESSURE DISTRIBUTION ON AN UNSWEPT WING WITH VARIOUS ARRANGEMENTS OF SPLIT FLAP. J.A. Lawford. Gt. Brit., RAE TN Aero.2384, July, 1955. 62 pp. Results of tests in the 4 x 3 in. low-turbulence wind tunnel on an RAE 101 airfoil section having a five per cent chord flap at varying angles of incidence, angle, aspect ratio, and chordwise station, with the pressure plotting data presented in tabular and graphical form covering pressure coefficients at flap center line and various spanwise positions, reattachment lengths at flap center line, and normal force and pitching moment coefficients as part of an analysis of flap effects on chordwise pressure distribution, and on normal forces and pitching moments obtained by integrating the pressure measurements.

Fluid Mechanics and Aerodynamic Theory

ANALYTICAL TREATMENT OF TWO-DIMENSIONAL SUPERSONIC FLOW. I - SHOCK-FREE FLOW. II - FLOW WITH WEAK SHOCKS. J.J. Mahony and R.E. Meyer. Philos. Trans. Royal Soc. (London), Ser. A, Feb. 9, 1956, pp. 467-515. 27 refs. Development of approximation methods to solve the general wave-interaction problem of steady, irrotational, homentropic flow of a perfect gas, with equations developed for shock-free and weak-shock flows, neglecting entropy changes, taking into account a convergent process based on line-

arized theory and a mode of reduction for equations of motion to linear hyperbolic differential equations with the solution dependent on Mach Number range using the Riemann method to calculate the pressure distribution in the first interaction region of a jet expanding from a perfect nozzle, or the expansion of a double-power series. Includes a study of shock in the hodograph plane, and discussion of effects of entropy on accuracy of solution.

CONTRIBUTION À L'ÉTUDE DE L'EFFET DE PAROI EN ÉCOULEMENT PLAN INCOMPRESSIBLE. I - THÉORIES ET DOCUMENTS EXPÉRIMENTAUX EXTÉRIEURS. II - THÉORIE ET EXPÉRIENCES NOUVELLES. Appendix I - EFFET BOUCHON POUR DES PLAQUES PLANES FACE AU VENT. Jacques Barbieux. France, Min. de l'Air PST 304, 1955. 247 pp. 25 refs. In French. Results of theoretical and experimental investigations; development of a new theory of wall effects, with calculations of the frame stress and strain, curvature of the aerodynamic area around a profile, and modifications of the general and local characteristics, extended to the case of compressible flow within the limits of the Prandtl law; and a comparison with tests at low speed on an NACA 63.015 profile, taking into account the effect of wing thickness. Includes an evaluation of measuring techniques and apparatus.

CONTRIBUTION À L'ÉTUDE DES MILIEUX POREUX. I - INTRODUCTION. II - ÉCOULEMENT PLAN. III - METHODE DE RELAXATION ET ÉCOULEMENT DE RÉVOLUTION. Mladen M. Boreli. France, Min. de l'Air PST 305, 1955. 129 pp. In French. Theoretical and experimental investigation of the problems of underground flow governed by gravity laws based on the Darcy findings using the analogy tank technique, and applying the theory of analytical functions of a complex variable to the study of plane and constant flow in porous media, with calculations for the rotating flow by means of the relaxation method as for the case of a shaft not attaining the impervious layer.

MEASUREMENT OF THE CROSS FLOW AROUND AN INCLINED BODY AT A MACH NUMBER OF 1.91. D.J. Raney. Gt. Brit., RAE TN Aero. 2357, 1955. 31 pp. Experimental results given in diagrams to show resultant cross-flow distribution on the upper (leeward) half of the cross-flow plane of the upwash and downwash around a body of revolution, measured in positions five and 13 calibers downstream from the nose at various angles of incidence. Analysis includes: a derivation of the cross flow at the rear position caused by the vortex pair shed from the body and their images by subtracting the incompressible potential cross flow around a two-dimensional circular cylinder from the calculated cross flow; an estimation of a corresponding theoretical cross flow due to the vortices under the assumption of infinitely long subsonic vortices of constant strength; and a comparison of the direction and relative magnitudes throughout the flow field of the derived and theoretical vortex cross flows, taking into account the factor of reliability of the parameters.

PRESSURE DISTRIBUTIONS: AXIALLY SYMMETRIC BODIES IN OBLIQUE FLOW. Appendix - BLOCKAGE CORRECTION. I.J. Campbell and R. G. Lewis. Gt. Brit., ARC CP 213, 1955. 27 pp. BIS, New York. &0.75. Derivation of pressure coefficients from fundamental concepts, with measurements of three varying parameters along the forward part of a body of revolution at various angles of incidence using ARL water-tunnel calculations for four axially symmetric head shapes. Results indicate the adequacy of the data for each head shape to determine the pressure coefficient and the peak suction at any point on the configurations at any angle of incidence.

SUPERSONIC FLOW PAST QUASI-CYLINDRICAL BODIES OF ALMOST CIRCULAR CROSS-SECTION. D.G. Randall. Gt. Brit., RAE TN Aero. 2404, Nov., 1955. 26 pp. 16 refs. Study based on linearized small-perturbation theory, with an evaluation of first eleven basic functions of disturbance velocity potential obtained as Fourier series. Results indicate applicability of the method to calculate flow over circular cylinder surmounted by canopy and to solve certain wing-body interference problems through an extension of results.

THE FINAL PERIOD OF DECAY OF NON-HOMOGENEOUS TURBULENCE. O.M. Phillips. Proc. Cambridge Philos. Soc., Jan., 1956, pp. 135--151. Analysis of the motion characteristics due to a general localized disturbance in an infinite fluid initially at rest, with the results applied to solve the case of the final period of an axially symmetrical turbulent wake consisting generally of the superposition of two types of motion through a derivation of expressions for the distribution of the mean-square vorticity and the energy spectrum tensor in the wake.

TURBULENCE MEASUREMENTS IN FREE SURFACE FLOW WITH AN IMPACT TUBE-PRESSURE TRANSDUCER COMBINATION. Appendix A - DETAILED ANALYSIS OF MECHANICAL SYSTEM OF GAGE 1-A. Appendix B. Appendix C - DESIGN AND PERFORMANCE CHARACTERISTICS OF GAGE WITH PIEZOELECTRIC CERAMIC PRESSURE TRANSDUCER. A.T. Ippen, R.S. Tankin, and F. Raichlen. MIT Hydrodynamics Lab. TR 20, July, 1955. 96 pp. 23 refs. Results of an ONR-sponsored theoretical and experimental investigation into the applicability of an impact tube in combination with a capacitance-type pressure transducer to measure mean turbulence properties, compared to those of hot-wire measurements obtained in air flow, with emphasis covering boundary-layer growth in open channel flow, the distribution of relative turbulent intensity depthwise through the flow, the variation of the velocity correlation coefficient and of the mean intensity spectrum in this direction, and of the characteristics of the wake of a circular cylinder in fully developed open-channel turbulent

flow, with the turbulence gage featuring a natural frequency of 150 cycles per sec., more than adequate for the 50 per cent of the turbulent flow energy below 5 cycles per sec. and 90 per cent below 30 cycles per sec. Results indicate that the gage design is useful to obtain reliable measurements of mean velocities, root mean square values of the turbulent velocity fluctuations, and scales of macroturbulence.

TWO-DIMENSIONAL SINK FLOW OF A VISCOUS, HEAT-CONDUCTING, COMPRESSIBLE FLUID, CYLINDRICAL SHOCK WAVES. T. Yao-Tsu Wu. (CIT Hydrodynamics Lab. Rep. 21-16, 1954.) Quart. Appl. Math., Jan., 1956, pp. 393-418. 13 refs. ONR-sponsored investigation of the problem of steady, cylindrical sink- or source-type flow, applying the Navier-Stokes equations for a viscous, heat-conducting perfect gas, under simplified assumptions, to obtain solutions for the case of a large Reynolds Number and to develop an analytical technique based on the Poincaré-Lighthill-Kuo (PLK) method for transonic and supersonic regions, taking into account the effects of entropy and viscosity coefficient variations of the fluid.

Internal Flow

THE EFFECT OF CHARACTER OF SURFACE ROUGHNESS ON VELOCITY DISTRIBUTION AND BOUNDARY RESISTANCE. H.H. Ambrose. U. Tenn. Dept. Civ. Eng., Final Rep. ONR-sponsored experimental investigation of turbulent flow through pipes with cylindrical depressions or projections as roughness elements, with results indicating: that the fully developed effect of depression roughness produces skimming flow with the increase in resistance coefficient over that of a smooth pipe proportional to the per cent of the depressed surface area but independent of the size and distribution of the depressions and with the transition dependent on the relative depth and the per cent of surface area; that projections of no more than 40 per cent surface area produce isolated-roughness or wake-interference flow depending on the relative proximity of the elements; and that the logarithmic velocity distribution applies to all types of turbulent flow in pipes for given wall distance values, taking into account the von Kármán Number.

EFFECT OF TRANSVERSE BODY FORCE ON CHANNEL FLOW WITH SMALL HEAT ADDITION. Simon Ostrach and F.K. Moore. US, NACA TN 3594, Feb., 1956. 31 pp. Analysis of the steady, compressible, inviscid channel flow subject to a transverse body force with heat addition at a cross-sectional plane and dependent on Mach and Froude Numbers and a dimensionless heat parameter applied to the case of flow in a rotor-tip combustor of a helicopter ram jet. Results indicate that for small Mach Numbers and uniform heat addition the flow is displaced in the direction of the body force with the velocity profile of uniform shear; and that a nonuniform heat addition in the cross-sectional plane leads to the superposition of strong vortex motions on the shear flow.

SOME EXPERIMENTS ON THE SECONDARY FLOW IN PIPE BENDS. J.H. Horlock. Proc. Royal Soc. (London), Ser. A, Feb. 21, 1956, pp. 335-346. Analysis, under the assumption of a sine curve for the center line of the bend, of the general behavior of the flow, solved as a nonlinear differential equation, with a variety of solutions obtained for different entry conditions and compared with experimental data. Test results indicate that high velocities are producable by the continual reversal of the radius curvature in bends.

FORMULAE AND DIAGRAMS FOR THE CALCULATION OF OPEN IMPELLER CENTRIFUGAL PUMPS. U.M. Barske. Gt. Brit., RAE TN RPD 127, Sept., 1955. 18 pp. Includes design, charts, and procedures to determine main dimension of the pump in terms of performance requirements for specialized applications, with data on impeller disc friction losses for liquids over a wide range of physical properties.

AN INVESTIGATION OF THE FLUTTER CHARACTERISTICS OF COMPRESSOR AND TURBINE BLADE SYSTEMS. Chi-Teh Wang, Frank Lane, and R.J. Vaccaro. J. Aero. Sci., Apr., 1956, pp. 335-344. WADC-sponsored investigations at NYU of different multiblade cascade systems in incompressible flow at low incidence. Analysis includes a development of a flutter mechanism with two degrees of freedom designed and constructed to test two-dimensional cascades at low speeds; and a comparison between experimental and theoretical findings. Results indicate that in the hypothetical treatment of fluttering blade systems the prohibitively large number of the degrees of freedom required for the analysis may be reduced greatly by recognizing the existance of a single equivalent blade to permit the actual carrying out of the flutter calculation, as for unstaggered cascades when flutter occurs with adjacent blades oscillating 180 degrees out of phase, in confirmation of the Lilley experimental observations, and for staggered cascades a complete change of the blade flutter mode from a predominant bending to a predominant torsion occurring from a very small change in blade inertial properties.

PRELIMINARY INVESTIGATION OF A FAMILY OF DIFFUSERS DESIGNED FOR NEAR SONIC INLET VELOCITIES. Appendix - FLOW UNIFORMITY. Richard Scherrer and W.E. Anderson. US, NACA TN 3668, Feb., 1956. 43 pp. 16 refs. Tests on a series of diffuser shapes defined by empirical equations having constants related to the initial boundary-layer thickness through the mass-flow range with a variety of attached and separated initial boundary layers, and on offset ducts with dif-

ferent surface conditions. Results indicate that in the nonuniform entry flow the extension of the entry length produces better pressure recovery and more steady and uniform flow at the duct exit station; that the initial slope must be zero near sonic entry conditions for the duct contour with or without boundary-layer compensation to have low initial pressure gradients; that the empirical interrelationship of the parameter and the maximum divergence angle provides high pressure recovery and steady uniform flow at high mass-flow ratios under a thin initial boundary layer; and that the largest losses occur with air leakage into the duct near the entry.

THE EFFECT OF VISCOSITY UPON THE CRITICAL FLOW OF A LIQUID THROUGH A CONSTRICTION. A.M. Binnie. Quart. J. Mech. & Appl. Math., Dec., 1955, pp. 394-414. Analysis of the motions of a viscous liquid under gravity, as over a broad-crested weir, with swirl subjected to pressure through a convergent-divergent nozzle under the assumption of a whole discharge passing through a laminar boundary layer neglecting the inlet length, of gradual constrictions, of favorable pressure gradients in the direction of streaming, and of polynomial form for the velocity distributions over the cross-sections. Includes calculation of first order differential equations satisfying the momentum integral equations indicating that the motion is critical not requiring the specification of the arbitrary inlet conditions, and that a long wave of small amplitude may be maintained stationary on the moving liquid at the critical cross-sections.

SOME TESTS ON THE SPREAD OF VELOCITY IN A COLD JET DISCHARGING WITH EXCESS PRESSURE FROM A SONIC EXIT INTO STILL AIR. J. Seddon and L. Haverty. Gt. Brit., RAE TN Aero. 2400, Nov., 1955. 16 pp. Experiments in the range of 40--200 diameters from the exit at jet pressure ratios (outside static pressure divided by jet total pressure) between 0.479--0.042, corresponding to isentropic Mach Numbers of 1.08--2.72. Results indicate no great difference in the rates of spread for a supersonic jet compared to that of a subsonic one, with the effective exit of an under-expanded jet displaced some distance downstream of the actual exit, and for a jet of isentropic Mach Number 1.51, the effective exit position is about eight diameters downstream and the half-velocity circles lie on a cone of semi-angle 5.7° from the center of the effective exit.

Wings and Airfoils

THE CALCULATION OF THE SPANWISE LOADING OF SWEPTBACK WINGS WITH FLAPS OR ALL-MOVING TIPS AT SUBSONIC SPEEDS. G.G. Brebner and D.A. Lemaire. Gt. Brit., RAE Rep. Aero. 2553, Sept., 1955. 54 pp. 18 refs. Analysis of results of Duquenne and Grandjean electric tank tests on 45° sweptback wings with trailing edge flaps to develop a method for the calculation of the spanwise loading in terms of the effect of sweep on the equivalent incidence of a section with flap, on the downwash factor, and on the spanwise loading distribution with an incidence discontinuity. Includes a computation of interpolation furmulae extending the results to wings of any sweep and flap span and a comparison of Thomas and Mangler results to the case of a wing with all-moving tip control.

DYNAMIC DERIVATIVES IN YAW AND SIDESLIP OF THIN WINGS AT SUPERSONIC SPEEDS. I - THE CURVED FLIGHT PATH, ZERO RATE OF CHANGE OF SIDESLIP. II - THE STRAIGHT FLIGHT PATH, RATE OF CHANGE OF SIDESLIP EQUALS RATE OF YAW. III - RATE OF CHANGE OF SIDESLIP AND YAW - A COMPARISON. T.R. Goodman. J. Aero. Sci., Apr., 1956, pp. 357-367. 10 refs. WADC-supported investigation at the CAL Flight Res. Dept. to determine stability parameters through a three-dimensional approach for a large variety of wings, with special emphasis on the motions of the rate of change of yaw and the rate of change of sideslip requiring the introduction of the characteristic parameter into the defining differential equation and boundary condition simultaneously, taking into account the rotationally induced sidewash and backwash on the wing, the orientation of the leading edge with respect to the free-stream velocity vector changing from instant to instant, and the boundary condition at the foremost surface of discontinuity.

THE FLOW AROUND A SUPERSONIC AEROFOIL. J.J. Mahony and P.R. Skeat. Australia, ARL AN 147, Oct., 1955. 15 pp. Derivation of an approximate solution for the pressure distribution in rotational supersonic flow of a perfect inviscid gas about a two-dimensional sharp-nosed biconvex airfoil with a ten per cent thickness ratio, neglecting the second order entropy changes across the shock waves, with a comparison to the simple shock-expansion theory, and with provisions for the error estimation for increasing Mach Numbers.

WING-BODY COMBINATIONS WITH CERTAIN GEOMETRIC RESTRAINTS HAVING LOW ZERO-LIFT WAVE DRAG AT LOW SUPERSONIC MACH NUMBERS. Harvard Lomax. US, NACA TN 3667, Feb., 1956. 32 pp. 10 refs. Analysis of variational problems involving several configurations in terms of requirements for minimum-wave drag, with emphasis on the effects of shortening the fuselage and of fixing the fuselage diameter at several points for the specific cases of wings centrally mounted on slender quasi-cylinders in terms of shortening the fuselage and of constrained fuselage areas; and wings centrally mounted on slender closed bodies of revolution in terms of unlimited indentation length and fixed volume, limited indentation length on a Sears-Haack body with fixed volume, and limited indentation on arbitrary bodies with fixed diameter and volume.

AEROELASTICITY

AEROELASTIC NUMBER. S. Neumark, A.S. Taylor, and H.H.B.M. Thomas. Gt. Brit., RAE TN Aero. 2389, Aug., 1955. 11 pp. Proposed development of a nondimensional parameter (ℰ) proportional to true air speed and air density related to flight conditions and involving the elastic characteristics of an airframe to be used in conjunction with Mach and Reynolds Numbers to obtain an expression for the static margin (K_n) of an aircraft in the case where aerodynamic coefficients are dependent on speed through compressibility, viscosity, and aeroelastic distortion effects and the maneuver margin and other stability and control criteria are taken into account.

GUST-LOAD AND AIRSPEED DATA FROM ONE TYPE OF TWO-ENGINE AIRPLANE ON SIX CIVIL AIRLINE ROUTES FROM 1947 TO 1955. Appendix - DETAILS OF METHOD OF EVALUATION AND ANALYSIS OF RECORDS. W.G. Walker. US, NACA TN 3621, Feb., 1956. 25 pp. 11 refs. Results indicate general agreement with the findings of previous studies for similar aircraft from V-G data analyzed in terms of gust-loads, and operating speeds, with potential application to routine operations in conjunction with time-history data (VGH).

PRELIMINARY EXPERIMENTS ON THE SIMULATION OF GUSTS IN A WIND TUNNEL. A. M. Kuethe, J.D. Schetzer, L.C. Garby, and R.L. Roensch. USAF TN 55-64, Mar., 1955. 46 pp. 40 refs. Analytical evaluation of the relative merits of techniques for generating reproducible gusts in a wind tunnel applying the aerodynamic lift-lag theory, with measurements for the moving-bump and vortex-type gust generators of the dynamic increment of lift separated from the quasi-steady values for a two-dimensional airfoil, as compared to theoretical data, and with details of a larger-scale gust-generator model under construction at the U. of Mich.

SPRING TAB FLUTTER. I - A THEORETICAL INVESTIGATION ON WING-AILERON-TAB FLUTTER. Appendix I - DIMENSIONS, DISTORTION MODES, AND ELASTIC STIFFNESSES OF AEROPLANES. Appendix II - INERTIAL COEFFICIENTS. Appendix III - AIR-LOAD COEFFICIENTS. R.A. Frazer and W.P. Jones. II - EXPERIMENTS ON BINARY AILERON-TAB FLUTTER. Appendix - THE POSITION OF THE NEUTRAL POINT FOR AN OFFSET BALANCING ARM. C. Scruton, J. Williams, and C.J.W. Miles. Gt. Brit., ARC R&M 2592 (July, 1942), 1955. 95 pp. BIS, New York. $5.75. Development of general rules for spring tab design to eliminate the flutter phenomena. Includes numerical application to two representative types of spring tabs using stability diagrams, with analytical and graphical methods based on the vortex strip theory, and with calculated binary flutter characteristics of a particular wing system.

TABULATION OF THE f_λ FUNCTIONS WHICH OCCUR IN THE AERODYNAMIC THEORY OF OSCILLATING WINGS IN SUPERSONIC FLOW. Vera Huckel. US, NACA TN 3606, Feb., 1956. 59 pp. 12 refs. Specific values of the parameters λ, M, and K tabulating f_λ and extending the use of the Van Borbély's recursion formula to obtain f_λ satisfactorily for at least $\lambda = 13$ or 14. Results indicate the convenience of intervals with respect to the Mach 1.2--5 range covering a fairly wide range of reduced frequencies at small intervals for general application; and the considerably higher values of arising in flexible rather than in rigid wings.

AERONAUTICS, GENERAL

IAS 24TH ANNUAL MEETING, NEW YORK, JAN 23-26, 1956: SUMMARY OF TECHNICAL SESSIONS. Aero. Eng. Rev., Apr., 1956, pp. 42-47, 88-126. Contents: Aerodynamics, Part I, H.T. Luskin. Aerodynamics, Part II, F.H. Clauser. Aeroelasticity, M.A. Biot. Aeronautical Engineering Education, J.W. Hoover. Air Space Use, J.F. Taylor, Jr. Air Transport, H.D. Hoekstra. Aircraft Design, R.G. Bowman. Aircraft Noise, William Littlewood. Earth Satellites, Paul Rosemberg. Electronics, H.G. Stever. Engineering Management Philosophies, E.A. Leeden. Flight Safety and Training, Jerome Lederer. Guided Missiles, M.C. Demler. Helicopter Dynamics, A.H. Flax. Helicopter Test and Development, N.M. Stefano. Hypersonics, Arthur Kantrowitz. Instruments, C.F. Savage. Internal Flow in Jet Engines, Abe Silverstein. Meteorology, A.F. Merewether. Rocket Propulsion, D.F. Ferris. Structures, Walter Ramberg. Thermal Stress Analysis, George Gerard. VTOL Aircraft, W.C. Fortune.

AIR TRANSPORTATION

THE ECONOMICS OF LARGE AIRCRAFT. Grover Loening. Aero. Eng. Rev., Apr., 1956, pp. 48-55. Relative efficiency, feasibility, and potentialities of large-scale use of transports for carrying bombers, fighters, and bulk cargo by air evaluated in terms of fundamental economics and design parameters and related aerodynamic, fuel, and piloting factors applied to high-speed aircraft.

AIRPLANE DESIGN

COMPARISON OF LANDING-IMPACT VELOCITIES OF FIRST AND SECOND WHEEL TO CONTACT FROM STATISTICAL MEASUREMENTS OF TRANSPORT AIRPLANE LANDINGS. E.N. Harrin

US, NACA TN 3610, Feb., 1956. 22 pp. Study of landing velocities, taking into account the effects of gusts, rolling direction, and number of engines. Results indicate the greater vertical velocity for the second wheel than the first wheel to contact, gusty winds increase the vertical velocities for both wheels, and that the effect of the direction of rolling increases the probability of exceeding a given high value of vertical velocity for the wheel toward which the airplane rolls just prior to initial impact.

SUMMARY OF SCALE-MODEL THRUST-REVERSER INVESTIGATION. J.H. Povolny, F.W. Steffen, and J.G. McArdle. US, NACA TN 3664, Feb., 1956. 49 pp. Study of the relative performance efficiency, other characteristics, and potentialities for aircraft control purposes of target, tail-pipe cascade, and ring cascade types, taking into account the effects of design variables and reversed-flow boundaries along with thrust-modulation parameters. Results indicate that the lip and end plate angles and target frontal area are the most significant geometric variables affecting target-type reverser performance; that for the tail-pipe-cascade type, cascade blade design, cascade length-to-width ratio, and external cascade doors have considerable effect on the reverse-thrust ratio at which the reversed flow attaches to the cowl; that the performance of the ring-cascade reverser is very sensitive to ring shape and spacing; and that all types have satisfactory thrust-modulation characteristics providing reverse-thrust ratios of over 40 percent, with the selection basis determined as being mainly installation convenience.

ELECTRONICS

AERIAL SYSTEMS FOR AIRCRAFT. R.A. Burberry. J. RAeS, Feb., 1956, pp. 101-113. Analysis of antenna design problems and procedures, including: fundamental operational classification by frequency ranges; electrical criteria based on radiation pattern, impedance, and gain factors applied to the dipole, loop, slot, and suppressed HF, VHF, and SHF types; flight test data, taking into account aerodynamic forces, vibration loads, thermal effects, and other mechanical aspects, and the effect of adjacent structures on aerial performance; and material requirements such as tensile strength and fatigue resistance of metals, electrical properties of insulators, and high-temperature characteristics of laminates.

AN EVALUATION OF HIGH FREQUENCY ANTENNAS FOR A LARGE JET AIRPLANE. O. C. Boileau, Jr. IRE Trans., ANE Ser., Mar., 1956, pp. 28-32. Performance comparison of five HF communication antenna configurations, with the impedance versus frequency characteristics explored over the 2--24 mc. range in terms of efficiency parameters.

THE PRACTICAL COMBINATION OF AIR NAVIGATION TECHNIQUES. H.J. Galbraith and N. Braverman. IRE Trans., ANE Ser., Mar., 1956, pp. 3-10. Recommendations to combine the reliability and continuity of dead-reckoning with intermittent "fixing" by use of accurate position data from ground and stellar referenced sources to increase operational capability and dependability, with an evaluation of methods of incerting position fixed and instrumentation of the associated wind-computation and wind-memory functions, and with provisions for corrections of system errors, taking into account weight reduction objectives.

RELIABILITY THROUGH REDUNDANCY. R.H. Hershey. IRE Trans., ANE Ser., Mar., 1956, pp. 16-20. Probability principles applied to the requirements of automaticity in complex airborne electronic systems, with the results of an analysis of a typical system used to develop a method minimizing failure on the basis of optimum design criteria related to the redundancy parameter.

SOME ELECTRICAL AND ELECTRONIC CIRCUITS IN FLIGHT TEST INSTRUMENTATION. G. E. Bennett. Gt. Brit., RAE TN Instn.149, Sept., 1955. 49 pp. 27 refs. Analysis of the output modifying operations of such types of electromechanical transducers as: electromagnetic generator, piezoelectric, and variable resistance, inductance, and capacitance transducers covering the conversion of the transducer output into a voltage or current, the combination of two or more outputs, amplification, removal of unwanted frequencies, integration and differentiation, the extension of the frequency range of the transducer, and the derivation of rates of change and time integrals.

EQUIPMENT

DEVELOPMENT OF R.A.E. AIR AND OIL CHARGING VALVE. I.J. Vaughan. Gt. Brit., RAE TN Mech. Eng. 195, 1955. 19 pp. Design for use in hydraulic and pneumatic systems as a replacement for the A.G.S. 1200 inflation valve at pressures up to 4000 psi, with an analysis of test results at various temperatures and pressures taking into account requirements of materials and production methods.

FLIGHT TESTING

ENGINEERING ASPECTS OF TEST FLYING. I, II. P. Brown and C.F. Bethwaite. J. SLAE, Jan., 1956, pp. 3 16. Includes analyses of such problems and their causes as instrumentation; cable provisions; airframe and equipment defects affecting the fuel, hydraulic, pneumatic, electric, and air pressurization systems and the flight controls, brakes, and power plants; prototype development and trials; ground servicing; methods for ascertain-

ing flying qualities; structural testing; and the probability basis of accessory systems failures.

FUELS AND LUBRICANTS

EFFECT OF DISSOLVED OXYGEN ON THE FILTERABILITY OF JET FUELS FOR TEMPERATURES BETWEEN 300° AND 400° F. A.B. McKeown and R.R. Hibbard. US, NACA RM E55I28, Dec. 28, 1955. 22 pp. 10 refs. Tests on JP-4 and JP-5 fuels in a bench-scale rig using filter paper as the filter medium, with the fuel residence time at high temperatures of approximately 6 sec., with the results indicating that the clogging characteristics of fuels increase with the increasing temperature and the dissolved oxygen concentration; and that the amount of insoluble material formed at high temperatures necessary to produce clogging of filters is of the order of 1 milligram per gallon of fuel.

EVAPORATION OF JP-5 FUEL SPRAYS IN AIR STREAMS. Appendix - CALCULATION OF FUEL-SPRAY EVAPORATION. H.H. Foster and R.D. Ingebo. US, NACA RM E55K02, Feb. 21, 1956. 26 pp. Investigation using a sampling-probe technique to determine percentage of evaporation of a low-volatility fuel under conditions common in ram-jet engines, with the fuel injected contrastream from a multiple-orifice injector into an Inconel pipe with preheated air passing through it. Analysis includes a derivation of an expression for the evaporation in terms of the difference in air and wet-bulb temperatures of the fuel drops, downstream distance between injector and sampler, fuel injection velocity, and the air velocity.

THERMAL STRESSES IN SOLID PROPELLANT GRAINS. R.D. Geckler. Jet Propulsion, Feb., 1956, pp. 93-97. Development of a computational method based on a first approximation obtained from the analytical solution assuming Young's modulus as being independent of temperature, and then finding a more accurate solution by numerical integration taking into account variations of the Young modulus with temperature.

AUTOCORRELATION ANALYSIS OF THE SLIDING PROCESS. Ernest Rabinowicz. J. Appl. Phys. Feb., 1956, pp. 131-135. 14 refs. ONR-supported investigation in the MIT Lubrication Lab. to determine experimentally sliding friction phenomena of junctions using statistical methods, with the friction force producing strain-gage measured deflections permanently registered on a Sanborn recorder Includes calculations comparing the instantaneous value of the friction force to that of previous estimates under the assumption that the asperities are circular cones of different shear strengths in contact with other similar cones over a flat region of contact, and with friction traces developed using apparatus having stationary spherically ended rider of one material and flat, slowly moving plate of another.

FRICTION STUDIES OF GRAPHITE AND MIXTURES OF GRAPHITE WITH SEVERAL METALLIC OXIDES AND SALTS AT TEMPERATURES TO 1000° F. Marshall B. Peterson and R.L. Johnson. US, NACA TN 3657, Feb., 1956. 16 pp. 13 refs. Results of an experimental investigation on various steel specimens and Inconel combinations using solid lubricants to reduce friction and wear between moving metal surfaces at high temperatures indicating individual lubricant properties of mixtures over various temperature ranges in terms of oxidation of the metal surfaces, taking into account the residual moisture of salts, with a comparison to those of resin-bonded films.

WEAR OF TYPICAL CARBON-BASE SLIDING SEAL MATERIALS AT TEMPERATURES TO 700° F. R.L. Johnson, M.A. Swikert, and J.M. Bailey. US, NACA TN 3595, Feb., 1956. 22 pp. Experimental investigation to determine the effect of temperature, type, and compositional changes in mating-surface materials on wear and surface failure characteristics of carbon-seals. Results indicate that wear of carbon materials increases rapidly at high temperatures in relation to formation of oxide films on mating surfaces, that wear reduces through the use of chromium-plated steel as the mating surface, and that in general the type of carbon and impregnation of the carbon seal have little effect on wear as compared to that of the mating material.

ICE FORMATION AND PREVENTION

EFFECT OF PNEUMATIC DE-ICERS AND ICE FORMATIONS ON AERODYNAMIC CHARACTERISTICS OF AN AIRFOIL. D.T. Bowden. US, NACA TN 3564, Feb., 1956. 59 pp. 13 refs. Investigation of the performance of a pneumatic-boot mechanical de-icing system, with measurements of lift, drag, and pitching moment on an NACA 0011 airfoil equipped with two types of pneumatic de-icers having spanwise and chorwise inflatable tubes. Results indicate the removal of the main part of an ice formation through boot inflation, with the ice remaining after inflation of the spanwise-tube de-icer increasing the airfoil section drag 7--37 percent for 0°--4.6° angle of attack over the ranges of airspeed, total air temperature, liquid-water content, and cycle times covered; with the drag increase becoming constant after a few de-icing cycles; with drag increases due to ice remaining on the chordwise-tube considered as being similar to those for the spanwise-tube de-icer; and with the minimum airfoil drag in icing, averaged over a de-icing cycle, obtained with a short de-icing cycle.

IMPINGEMENT OF WATER DROPLETS ON A RECTANGULAR HALF BODY IN A TWO-DIMENSIONAL INCOMPRESSIBLE FLOW FIELD. William

Lewis and R.J. Brun. US, NACA TN 3658, Feb., 1956. 27 pp. 13 refs. Investigation of impingement patterns on airfoils and other aircraft components by calculating trajectories of water droplets in a downstream direction, with equations of motion expressed in terms of two dimensionless parameters and solved by means of a mechanical differential analyzer. Application of the data to estimate the collection efficiency of the central portion of the rotating-disc icing-rate meter and the rectangular bars for spray distribution measurements in an icing wind tunnel.

IMPINGEMENT OF WATER DROPLETS ON AEROFOILS. Appendix I - CALCULATION OF COLLECTION EFFICIENCY OF N.A.C.A. 65A008. Appendix II - TO DETERMINE THE EFFECT OF AIRSPEED ON THE COLLECTION EFFICIENCY OF N.A.C.A. 65A008 AEROFOIL. F.J. Bigg and J.E. Baughen. Gt. Brit., RAE TN Mech. Eng. 208, Sept., 1955. 59 pp. 13 refs. Development of a generalized simple method to determine collection efficiency on airfoils at different angles of incidence under varying icing conditions through an analysis of published data on water-droplet catch, considering collection efficiency as a function of a dimensionless parameter, thickness-to-chord ratio, and the frontal projected thickness of the airfoil.

AN OIL-STREAM PHOTOMICROGRAPHIC AEROSCOPE FOR OBTAINING CLOUD LIQUID-WATER CONTENT AND DROPLET SIZE DISTRIBUTIONS IN FLIGHT. P.T. Hacker. US, NACA TN 3592, Jan., 1956. 36 pp. 26 refs. Development, wind-tunnel, and flight testing using water sprays from the airborne cloud aeroscope operating in icing and nonicing conditions by capturing continuously the cloud droplets in an oil stream, with the results indicating that the liquid-water content of the cloud can be calculated from the geometry of the aeroscope, the airspeed, the oil-flow rate, and the known droplet size distribution.

MATERIALS

EFFECT OF STRESS ON THE EXPANSION COEFFCIENT. A.R. Rosenfield and B.L. Averbach. J. Appl. Phys., Feb., 1956, pp. 154-156. ONR-sponsored investigation at MIT using electrical strain gages to measure expansion coefficients under applied loading and after their removal, with results indicating that below a certain elastic limit the coefficient increases linearly returning to the original value with the removal of the load, and that with an exceeded elastic limit the coefficient is discontinuous without returning to the original value when unloaded.

ON THE PERMEABILITY OF POROUS MATERIALS. E.C. Yates, Jr. US, NACA TN 3596, Jan. 1956. 31 pp. 15 refs. Application of test results to the design of area-suction installations on wings, flaps, inlets, and wind tunnels. Includes methods to calculate calibration curves under conditions of a nonfixed relationship between Mach and Reynolds Numbers and to determine the influence of choking of the flow following the occurrence of sonic velocity within the pores, bending of the material, and in the case of wire cloth, the rolling of the material.

Metals and Alloys

THE COMPRESSION STRENGTH OF ALUMINIUM ALLOY SHEET MATERIALS TO SPECIFICATIONS D.T.D.546B, D.T.D.646B and D.T.D.687A. M.J. Henwood. Gt. Brit., RAE TN Struc.176, Oct., 1955. 22 pp. Results of compression tests on 16 S.W.G. small rectangular sheet and bar aluminum alloy specimens covering the region of the stress-strain curve up to 0.5% Proof Stress, with calculations of the mean compression strength and associated tensile values, and with typical stress-strain and tangential curves tabulated.

INVESTIGATION OF THE COMPRESSIVE STRENGTH AND CREEP LIFETIME OF 2024-T3 ALUMINUM-ALLOY PLATES AT ELEVATED TEMPERATURES. E.E. Mathauser and W.D. Deveikis. (US, NACA RM L55E11b, 1955.) US, NACA TN 3552, Jan., 1956. 40 pp. Results of strength tests indicating the validity of the previously developed relation for predicting plate compressive strength for all materials at room temperatures related to data on elevated-temperature strength and of creep-lifetime presented in the form of master creep-lifetime curves by using a time-temperature parameter. Includes a method of plate-creep failure stresses using the time-dependent stress-strain curves.

THE CHROMIUM-RICH ALLOYS OF THE CHROMIUM-TITANIUM-TUNGSTEN SYSTEM AT 900° AND 1200° C. N. Ryan. Australia, ARL Rep. Met. 13, July, 1955. 14 pp. Results of metallographic and X-ray tests indicating that the alpha tungsten and the compound $TiCr_2$ in alpha chromium differ considerably in the limits of solid solubility at both temperature levels and that the three-phase field of alpha chromium, alpha tungsten, and $TiCr_2$ is formed by the eutectoid reaction between the three phases.

Nonmetallic Materials

PLASTICS STRUCTURES. G.C. Hulbert. J. RAeS, Feb., 1956, pp. 114--120. Analysis based on test results of mechanical and fabricational properties of glass or asbestos fibers stabilized by phenolic, polyester, epoxide, and silicone resins in terms of the permanence of behavior under weather and environmental conditions and of fatigue, creep,

and temperature resistance to obtain a high degree of efficiency within defined parameters of loading, taking into account size, quantity, and complexity of structures.

SEBALKYD DOUGHS. A.C. Cornwell. Gt. Brit, RAE TN Chem.1265, Oct., 1955. 11 pp. Development of gap-filling materials to expand and harden in place without external heating used to fill and seal inaccessible cavities at strategic points in aircraft structures subjected to vibration causing movements between sealed skins. Includes analyses of: the relative merits and potentialities and of possible modifications of the plastic foam to obtain increased modulus, strength, and heat resistance utilizing fibrous fillers and rubbery doughs; alkyd resin requirements; and the factors of mixing techniques, parting agents, and surface priming.

MATHEMATICS

METHOD AND TABLES FOR DETERMINING THE TIME RESPONSE TO A UNIT IMPULSE FROM FREQUENCY-RESPONSE DATA AND FOR DETERMINING THE FOURIER TRANSFORM OF A FUNCTION OF TIME. Appendix - NUMERICAL EVALUATION OF DUHAMEL INTEGRAL. C.R. Huss and J.J. Donegan. US, NACA TN 3598, Jan., 1956. 38 pp. Simplified techniques for evaluating linear systems in flight-test data analysis, to determine the time response through the use of staircase-type functions having frequency intervals of such height that the area under each step equals that of the portion of the curve within the interval, and for the Fourier transform, fitted with constant time intervals.

NAVIGATION

THEORY OF ASTRO-NAVIGATION AND DEVELOPMENT OF EQUIPMENT UP TO 1945. D. Martin. Gt. Brit., RAE Rep. IAP.1466 (Monograph 2.5.07), Sept., 1955. 30 pp. Basic principles underlying Astro-Navigation methods, with the analysis including: a comparative evaluation of the relative merits of the methods and those of radar techniques; details of the Mk.IXA automatic averaging sextant, the Astrograph, and the Astro-compass developed during World War II; and a discussion of the problem of daylight Astro-Navigation.

PARACHUTES

THE EFFECT OF WATER ON THE POROSITY OF PARACHUTE FABRICS. II. J.E. Swallow. Gt. Brit., RAE TN Chem.1268, Oct., 1955. 11 pp. Measurement of the reduction of the porosity by blowing a mixture of water and air through cotton, nylon, Fortisan, and Terylene fabrics into the airstream of the testing instrument under simulated rain conditions to confirm results obtained by passing only air through fabrics under a layer of water and to determine the effects of varying pressure exerted on a fabric by wetting. Results indicate that for a given airflow the pressure on wet fabrics is greater than on dry fabrics by an amount equal to, or a little greater than, the threshold pressure.

POWER PLANTS

A COMPARATIVE INVESTIGATION OF A HOMOGENEOUS COMBUSTION CHAMBER WITH A TWO-STAGE COMBUSTION CHAMBER. E.A. DeZubay. Jet Propulsion, Feb., 1956, pp. 77--80, 97. Performance analysis of idealized systems with fuel and air reacting chemically in a single, thoroughly mixed, constant flow combustion chamber and with fuel reacting initially in one chamber with only a fraction of the total air and an addition of the remaining air completing the reaction in a separate chamber, under the assumption that the mixing in both reactors is instantaneous and that the intermediate mixing zone is infinitesimally small. Calculations include an evaluation of the maximum fuel rate, values of temperature and combustion fractions, and the variation of heat release with combustion efficiency.

EXPERIMENTAL AND CALCULATED TEMPERATURE AND MASS HISTORIES OF VAPORIZING FUEL DROPS. Appendix A - THEORETICAL CALCULATION FOR UNSTEADY STATE WITH FINITE LIQUID THERMAL CONDUCTIVITY. Appendix B - THEORY OF SIMULTANEOUS MASS TRANSFER AND HEAT TRANSFER. Appendix C - CALCULATION FOR LIFETIME OF A VAPORIZING DROP UNDER DIFFERENT AIR VELOCITIES. M.M. El Wakil, R.J. Priem, H.J. Brikowski, P.S. Myers, and O.A. Uyehara. US, NACA TN 3490, Jan., 1956. 82 pp. 20 refs. Application of test results to analyze jet-engine fuel intake and combustion problems indicating under the assumption of infinite thermal conductivity the unsteady state or time required for the drop to reach the wet-bulb temperature in terms of an appreciable amount of total vaporization time and of the validity of the circulation inside the drop confirming the need for correction factors for heat transfer and unidirectional diffusion to express the effect of mass transfer. Analysis includes: calculations using different heat transfer correlations, with the value of the diffusion coefficient showing the biggest variation, and applying those of Ranz and Marshall having the highest computed value of the coefficient to develop curves in reasonable agreement with experimental ones; an evaluation of the effect and extent of heat transfer down the thermocouple wires supporting the drop; and measurements of temperature histories of the vaporizing drops of binary mixtures and of fuels vaporizing at such high temperatures to cause burning.

FLAME SPREADING FROM BAFFLES. R.J. Petrein, J.P. Longwell, and M.A. Weiss. Jet Propulsion, Feb., 1956, pp. 81-86, 97. 16 refs. NAVORD-supported experimental study of the prob-

lem in two-dimensional turbulent ducted flow, with measurements of combustion efficiency, pressure effects related to turbulence, and fuel vaporization, taking into account the approach velocity, tailpipe length, baffle size, spacing and blockage, and duct size and indicating a transitional region in the flame stabilizing mechanism.

PERFORMANCE CHARACTERISTICS OF CYLINDRICAL TARGET-THRUST REVERSERS. F.W. Steffen and J.G. McArdle. US, NACA RM E55I29, Jan. 11, 1956. 40 pp. Test results indicating that the reverse-thrust performance is affected by the reverser frontal area, lip angle, and end-plate angle and depth; that the spacing required for unrestricted nozzle flow is influenced by the frontal area, reverser depth, lip and end-plate angles; that for reverse-thrust ratio greater than 64 per cent the reversed flow attaches to the 7° cowl in quiescent air; that the swept-type cylindrical reversers are generally unstable; and that the thrust-modulation characteristics of a cylindrical target-type thrust reverser are satisfactory.

PRODUCTION

THE APPLICATION OF NONDESTRUCTIVE TESTING BY A MANUFACTURER OF MILITARY AIRCRAFT. W.J. Maloney, Jr. Aero. Eng. Rev., Apr., 1956, pp. 76-84. Appraisal of the relative merits of the Fairchild quality control program to detect defects in parts and materials evaluated in terms of typical military requirements, using radiographic, penetrant, ultrasonic, and magnetic particle inspection techniques and spectrometers, mechanical impedance and hardness testers, metal comparators, magnegages, and magnatests to measure physical properties.

ROTATING WING AIRCRAFT

ANALYTICAL DETERMINATION OF THE NATURAL COUPLED FREQUENCIES OF TANDEM HELICOPTERS. Appendix - PROCEDURE FOR REDUCING THE ORDER OF THE MATRIX EQUATION. G.W. Brooks. IAS 24th Annual Meeting, New York, Jan. 23--26, 1956, Preprint 620. 18 pp. Members, $0.50; nonmembers, $0.85. Development of a method using the Lagrange dynamical equations for free vibration covering such degrees of freedom as translation, pitching and bending of the fuselage; translation, flapping and bending of the blades; and translation of the engine, with the elements of the determinant of the matrix equation including the natural frequencies, mode shapes, and mass distributions of the uncoupled components of the helicopter. Results indicate that for a particular type the coupled frequencies vary with rotor speed as related to the effect of changes in the structural properties of individual helicopter components.

CHARTS FOR ESTIMATING ROTOR-BLADE FLAPPING MOTION OF HIGH-PERFORMANCE HELICOPTERS. R.J. Tapscott and Alfred Gessow. US, NACA TN 3616, Mar., 1956. 19 pp. Theoretically derived charts, applicable to flight conditions involving high inflow velocities and large regions of reversed velocity, to calculate directly steady-state, first- and second-harmonic flapping coefficients for rotors having hinged rectangular blades with a linear twist of 0°, -8°, and -16° analyzed for combinations of inflow ratio to blade pitch angle at tip-speed ratios of .05 to 0,50. Theoretical basis excludes small angle assumptions for blade-section inflow angles and velocities as well as stall or compressibility effect except for an approximate allowance for stall in the reversed-velocity region.

A COMPARISON OF THE CALCULATED AND OBSERVED FLUTTER CHARACTERISTICS OF A HELICOPTER ROTOR BLADE HAVING BOTH CONTROL SYSTEM AND BLADE FLEXIBILITY. Appendix A-- SOLUTION FOR THE FLUTTER SPEED AND THE FLUTTER FREQUENCY. Appendix B - NUMERICAL EVALUATION OF THE COEFFICIENTS OF THE FLUTTER EQUATIONS FOR THE TEST BLADES. Appendix C - TYPICAL NUMERICAL SOLUTION (CONFIGURATION #3). Leonard Goland and A.A. Perlmutter. Princeton U. Dept. Aero. Eng. Rep. 333, Dec., 1955. 35 pp. Development of an analytical method to determine the rotor blade behavior in hovering flight using a Rayleigh-type approach based on an accurate determination of the aerodynamic center location, torsional frequency, and the effective slope of the lift curve of the blade and on the effects of unsteady aerodynamics. Includes calculations of the effect of mass distribution with constant control stiffness, with results similar to those of the NACA fixed-wing flutter theoretical predictions indicating a slight reduction of the rotor speed at flutter due to the increase of the tip-speed ratio, and the influence of calculated parameters on the predicted values.

AN INVESTIGATION OF HELICOPTER DESCENT AND LANDING CHARACTERISTICS FOLLOWING POWER FAILURE. E.F. Katzenberger and M.J. Rich. J. Aero. Sci., Apr., 1956, pp. 345-356. Analysis in terms of time histories of the descent velocity following partial or complete power failure for the critical case of vertical take-off, with a determination of the time rate of change of descent velocity and velocity at ground contact using pilot control inputs representative of pilot capabilities and helicopter characteristics representative of current designs. Includes a treatment of the special case of steady-state autorotative descent and landing; and a derivation of an index comparing designs as to autorotative landing capabilities.

INVESTIGATION OF THE PROPULSIVE CHARACTERISTICS OF A HELICOPTER-TYPE PULSEJET ENGINE OVER A RANGE OF MACH NUMBERS AND ANGLE OF YAW. P.J. Carpenter, J.P. Shi-

vers, and E.E. Lee, Jr. US, NACA TN 3625, Jan., 1956. 24 pp. Tests in the Langley 16 ft. transonic tunnel on engines mounted on a simulated helicopter rotor blade at Mach Numbers of 0.25 and of 0.3--0.6 and at yaw angles of 0°, 10°, and 20°. Results indicate that the maximum engine propulsive thrust is of approximately 1 lb. per sq. in. of frontal area up to 0.45 Mach Number and at Mach 0.5 and 0.6 it decreases to 0.94 and 0.73 lb. per sq. in.; that the minimum specific fuel consumption of 5.3 lb. of fuel per hour per h.p. occurs between 0.4 and 0.5 Mach Numbers; that the yaw angles have little effect on the engine propulsive characteristics; and that a comparison of whirling and nonwhirling data show significant performance losses due to whirling above centrifugal accelerations of about 200 g.

A TWO-DIMENSIONAL APPROXIMATION TO THE UNSTEADY AERODYNAMICS OF ROTARY WINGS. Appendix A - INFLUENCE OF BLADES OTHER THAN THE REFERENCE BLADE. R.G. Loewy. IAS 24th Annual Meeting, New York, Jan., 23 - 26, 1956, Preprint 605. 31 pp. 23 refs. Members, $0.65; nonmembers, $1.00. Theoretical investigation, taking into account the shed vorticity beneath the plane of the rotor disc, includes the effect of inlow ratio, number of blades in the rotor, shaping between the motion of adjacent blades, and the ratio of oscillatory to rotational frequency. Includes calculations of the blade lift and moment in a rotor with an arbitrary number of blades of arbitrary motion phase using the coefficients of an equivalent single-bladed rotor; of single-degree-of-freedom flutter in pitching motions at low inflow and of damping over a range of ratios of oscillatory to rotational frequency as a function of the pitch axis location. Results indicate the difference in the inflow values of a rotary wing as compared to those of fixed wings.

SPACE TRAVEL

ROCKET AND SATELLITE STUDIES DURING THE IGY. Joseph Kaplan. Aero. Eng. Rev., Apr., 1956, pp. 64-67. Appraisal of problems, trends, and practical progress in the techniques of upper-atmospheric research stages leading to American participation in a world-wide earth satellite program, with a description of present plans and organizations.

STRUCTURES

ANALYSIS OF FRAMEWORKS IN THE PRESENCE OF STEADY CREEP. P.G. Hodge, Jr. and B. Venkatraman. Polytech. Inst. Bklyn. Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 333, Nov., 1955. 29 pp. 11 refs. Experimental investigation of the problem using methods based on principles of minimum potential and minimum complementary energy, taking into account the Prager, Freudenthal, and Hoff findings.

THE EFFECT OF TIGHT CLAMPING ON THE FATIGUE STRENGTH OF JOINTS. W.A.P. Fisher and W.J. Winkworth. Gt. Brit., ARC R&M 2873 (Feb., 1952), 1955. 10 pp. BIS, New York. $0.75. Experimental tests on Z-section stringers connected to long, slotted cleats and on bolted joints in aluminum-alloy specimens, with results indicating that the tight clamping increases considerably the endurance; includes measurements of temperature and friction effects.

LOCAL INSTABILITY PROBLEMS OF LIGHT ALLOY STRUTS. Appendix I - THE STABILITY OF A SINGLE FLAT PLATE UNDER KNOWN EDGE CONDITIONS. P.S. Bulson. ADA Res. Rep. 29, Dec., 1955. 75 pp. 32 refs. Theoretical and experimental investigation on thin-walled aluminum extrusions with hinged ends using compression testing machines, with an evaluation of previous findings and of the theory of thin plates as applied to specific extrusion shapes. Results, expressed graphically as maximum stress per length, and maximum stress over the length-radius of gyration ratio for each extrusion shape as compared to Euler theoretical curves, indicate that substantial lips on extrusion flanges postpone local buckling until the plastic range is reached.

O GEOMETRYCZNYCH METODACH BADANIA KONSTRUKCJI PRĘTOWYCH (GEOMETRICAL METHODS OF INVESTIGATION OF LATTICE STRUCTURES). Witold Wierzbicki. Rozprawy Inżynierskie (Warsaw), No. 2, 1955. 62 pp. In Polish, with summaries in English and Russian. Solution of problems of structural mechanics based on the principle of the parallelepiped of forces; application of the Maxwell-Mohr equation for the displacement of lattice knots and derived general equation for a lattice to problems of solid systems; calculation of the formula for the deflection of a cantilever beam by means of secondary moments, taking into account the influence of the variability of cross-section on the statically indeterminate quantities, and using an equation for geometrical addition of deformations for frame computation, with the method of finite differences used to obtain a solution of the problem of a polygonal frame.

THEORY OF BENDING OF ISOTROPIC FLAT SANDWICH PLATES AND ITS APPLICATIONS. Ken Ikeda. J. Japan Soc. Aero. Eng., Nov.-Dec., 1955, pp. 11-17. In Japanese. Application to cases in which the individual stiffness of the facings or of

the core must be taken into account when compared to the total bending stiffness in the analysis of the basic problem under the assumption that the deformation of irrotational fancings produced by bending in the parallel plane of the surface. Results, as compared to those of the ordinary plate theory, provide solutions satisfying three boundary conditions for one edge of the plate. Applied examples include problems concerned with the deflection of plates subjected to transverse pressure and the buckling due to edge compression.

THE THEORY OF PLASTICITY: A SURVEY OF REGENT ACHIEVEMENTS (JAMES CLAYTON LECTURE). William Prager. IME Proc., No. 21, 1955, pp. 41-57. 168 refs. Includes an evaluation of fundamental aspects of shakedown and limit analysis applied to two- and three- dimensional problems of large deformations; results of impact testing and blast damage; developments in the theory of structural stability in the plastic range related directly to research areas in mechanical engineering; and a comprehensive bibliography.

Beams and Columns

COLUMN TESTS ON SOME PROPOSED ALUMINIUM STANDARD STRUCTURAL SECTIONS. R. E. Smith. ADA Res. Rep. 28, Nov., 1955. 43 pp. 17 refs. Experimental investigations at various slenderness ratios on equal and unequal bulb angles, lipped channels, and lipped H-sections using special platens in order to obtain a uniform load distribution. Analysis includes an evaluation of a method to apply the general theory of buckling of thin-walled sections and to calculate the warping constant and position of shear center. Results indicate that the failure occurs from the combination of torsional and flexural buckling and from the increase in torsion by decreasing slenderness ratio.

PLASTIC FLOW IN A BEAM COMPRESSED BY THREE DIES. W. Freiberger. Australia, ARL Rep. SM. 229, July, 1955. 9 pp. Results of approximate calculations under the assumption of perfect plasticity and plane strain using discontinuous stress and velocity fields satisfying boundary conditions to determine an upper and lower bound to the limit pressure and to indicate the deformation of the boundaries at the moment of pronounced plastic flow.

Cylinders and Shells

AXIALLY-SYMMETRIC MOTIONS OF THICK SHELLS. I. Mirsky and G. Herrmann. Columbia U. Inst. Air Flight Struc. AF TN 2, Nov., 1955. 21 pp. Study of the free harmonic waves in thick elastic cylindrical shells based on an approximation theory and the three-dimensional theory of elasticity, with calculations of the dependence of the displacement component on the coordinate in the direction of the normal to the middle surface, of the stress equations of motion and the appropriate boundary and initial conditions applying the Hamilton principle and Neumann uniqueness theorem, and of the stress-displacement relations using Hooke law for a three-dimensional elastic isotropic continuum.

HOLLOW CIRCULAR CYLINDER UNDER PERIODIC FLUCTUATIONS OF TEMPERATURE. Václav Vodička. Appl. Sci. Res., Sect. A, No. 5, 1955, pp. 327-337. Extension of results of investigation on heat waves in homogeneous isotropic circular cylinders, with the analysis under the most general assumptions, taking into particular account the case of boundaries of a body impervious to heat with the respective coefficients of the heat transfer tending to zero.

STRESS CONSIDERATIONS IN THE DESIGN OF PRESSURISED SHELLS. Appendix I - SPHERICAL SHELL WITH REINFORCED CIRCULAR OPENING. Appendix II - SPHERICAL SHELL WITH CAP OF GREATER THICKNESS. Appendix III - SHELL REINFORCED BY WIDELY SPACED FRAMES (NO STRINGERS). Appendix IV - SHELL REINFORCED BY WIDELY SPACED FRAMES (WITH STRINGERS). Appendix V - NEUTRAL HOLES IN DEVELOPABLE SURFACES. Appendix VI - EFFICIENCY OF ECCENTRICALLY PLACED REINFORCEMENT. E. H. Mansfield. Gt. Brit., ARC CP 217, 1955. 27 pp. BIS, New York. $0.75. Derivation of formulas to predict maximum stresses in thin-walled spherical, cylindrical, or conical shells subjected to internal pressure, with a reinforced circular opening and a cap of greater thickness for the spherical case, with stringers and closely spaced frames, stringers and widely spaced frames, and end caps of various forms for the cylindrical case, and with provisions to allow for reduced efficiency of the reinforcement on one side of the shell wall and to determine the feasibility of neutral holes with developable surface.

Thermal Stress

INFLUENCE OF AERODYNAMIC HEATING ON THE EFFECTIVE TORSIONAL STIFFNESS OF THIN WINGS. Appendixes A, B - FREE-END EFFECT ON THERMAL STRESS AND TORSIONAL STIFFNESS. Bernard Budiansky and J. Mayers. IAS 24th Annual Meeting, New York, Jan. 23--26, 1956, Preprint 579. 27 pp. Members, $0.65; nonmembers, $1.00. Results of a theoretical analysis indicating considerable losses of effective torsional stiffness in solid wings of symmetrical double-wedge cross section accelerated to supersonic speeds due to chordwise mass variations, taking into account the influence of Mach Number, acceleration, and thickness ratio.

A PRELIMINARY STUDY OF THE EFFECTS OF KINETIC HEATING ON THE DESIGN AND TESTING

OF AIRCRAFT STRUCTURES. W.H. Horton. Gt. Brit., RAE TN Struc. 177, Oct., 1955. 48 pp. 67 refs. Evaluation of the stress analysis and of changes in methods with the introduction of kinetic heating, including new problems in creep and thermal fatigue, with a description of automatic ground simulation. Includes results of the study of physical and mechanical behavior of materials under various temperature conditions in terms of thermal conductivity and expansion.

SOME STRUCTURAL AND AEROELASTIC CONSIDERATIONS OF HIGH-SPEED FLIGHT (THE NINETEENTH WRIGHT BROTHERS LECTURE). R.L. Bisplinghoff. J. Aero. Sci., Apr., 1956, pp. 289--329, 367. 62 refs. Review of results of analytical and experimental investigations applied to the study of the prime aerothermoelasticity problems in structural design of manned aircraft for sustained flight in the isothermal atmosphere up to about Mach Number 3.5, taking into account the fundamental factors of convective and external radiative heat transfer from the boundary layer into the structure interacting with internal heat transfer and modes of failure under combined gust, maneuvering, and random loadings. Includes an assessment of the requirements of basic design research and developmental trends, areas, and possibilities; and recommended methods of attack and alleviating the interrelated thermal stress and aeroelastic problems.

TRANSIENT THERMAL STRESSES IN BRITTLE CIRCULAR CYLINDERS. Appendixes I, II - THEORETICAL BASIS FOR COMPUTATION OF MEAN AND SURFACE TEMPERATURES OF CYLINDERS. E. Glenny and P.W.H. Howe. Gt. Brit., NGTE Memo. M.259, Jan., 1956. 33 pp. Development of a method based on elastic theory to determine the effects of thermal shock on brittle materials using calculations of the surface tensile stresses from computed temperature distributions in the material, with tests using high-alumina cylinders of varying diameters at different temperatures and a fluidized bed as a cooling medium at controlled heat-transfer rates. Results indicate that the surface stresses cracking the cylinders in a single cooling cycle and lowering their bend strengths appreciably are slightly greater than the measured mean tensile strength of the material; and that within reasonable allowances the theoretical predictions are experimentally substantiated.

THERMODYNAMICS

EXPERIMENTAL INVESTIGATION OF AIR-FLOW UNIFORMITY AND PRESSURE LEVEL ON WIRE CLOTH FOR TRANSPIRATION-COOLING APPLICATIONS. P.L. Donoughe and R.A. McKinnon. (US, NACA RM E52E16, 1952.) US, NACA TN 3652, Jan., 1956. 28 pp. Tests on regions of low permeability with calculations of the effect of exit pressure level on 20 x 200, 20 x 250, and 20 x 500 mesh wire cloth. Results indicate that for a 36 per cent reduction in the original thickness of the cloth the control of the calendering to ± 0.0002 in. yielded uniform air flow within ± 5 per cent; that the effect of the pressure level for exit pressures at 0.6 to 2.5 atmospheres is predictable by known analytical relations in the corrected mass flow range up to 0.004 lb. per sec.- in.; and that the reduced tensile strength of the cloth, in the direction of the primary stresses, is 1 1/2 to 3 times as large as the strength of the best porous sintered material presently available.

GENERALIZED TABLES OF CORRECTIONS TO THERMODYNAMIC PROPERTIES FOR NONPOLAR GASES. H.W. Woolley and W.S. Benedict. US, NACA TN 3272, Mar., 1956. 62 pp. 19 refs. Development of tables based on the Lennard-Jones 6-12 potential for representation of second and third virial coefficients and equation-of-state corrections for density, enthalpy, entropy, specific heats at constant pressure and volume, the ratio of specific heats, the isentropic expansion coefficient, and the velocity of sound to calculate the effects on nonpolar gases of gas imperfection.

HEAT CAPACITY LAG OF GASEOUS MIXTURES. T.D. Rossing, R.C. Amme, and Sam Legvold. US, NACA TN 3558, Mar., 1956. 35 pp. 18 refs. Experimental investigation of relaxation times for the excitation of molecular vibrations in a number of heavy gases using a Pierce-type acoustic interferometer to measure the sonic dispersion. Results indicate the strength of the intermodal coupling in the halogen-substituted methanes, the importance of binary collisions in the excitation of vibrations, the probability in a given collision of exciting or deexciting molecular vibrations depending upon the relative energy of approach of the colliding molecules rather than upon their relative velocity as predicted by the Landau-Teller theory, and the dependance of the steric factor on temperature as related to rotational velocity.

PREPARATION AND PROPERTIES OF HIGH TEMPERATURE PYROLYTIC CARBON. A.R.G. Brown. Gt. Brit., RAE Rep. Met.87, June, 1955. 58 pp. 42 refs. Development of a method to prepare massive specimens of carbon by the breakdown of hydrocarbon gases at various temperatures and sub-atmospheric pressures, with results indicating that the rate of deposition, density, electrical resistivity, and thermal conductivity of the deposits are dependent on temperature of deposition.

VISUAL STUDY OF FREE CONVECTION IN A NARROW VERTICAL ENCLOSURE. E.M. Sparrow and S.J. Kaufman. US, NACA RM E55L14a, Feb. 16, 1956. 14 pp. Investigation, using a shadowgraphic technique, of free-convection flow of water in an enclosure cooled at the top through a copper surface and heated from the open bottom. Results indicate that the flow is unsteady with time having no definite pattern, with the dominating characteristics being instability and change.

VERTICAL TAKE-OFF AIRCRAFT

INVESTIGATION OF THE EFFECTS OF GROUND PROXIMITY AND PROPELLER POSITION ON THE EFFECTIVENESS OF A WING WITH LARGE-CHORD SLOTTED FLAPS IN REDIRECTING PROPELLER SLIPSTREAMS DOWNWARD FOR VERTICAL TAKE-OFF. Richard E. Kuhn. US, NACA TN 3629, Mar., 1956. 38 pp. Results of the Langley Aero. Lab. development in the 7 x 10 ft tunnel on models at zero forward speed, based on previous tests to provide direct lift without inclining either the fuselage or the propellers through large angles with respect to the ground, indicating that with propeller thrust axis on the wing chord plane, both the angle through which the slip stream is deflected and the ratio of resultant force to thrust are reduced as the ground is approached; that the lowering of the thrust axis below the wing chord plane reduces the adverse effects of the ground and the large diving moments associated with the slotted flap arrangement; and that the static thrust efficiency is slightly reduced by ground effect.

PROBLEMS IN THE DESIGN OF PROPELLER-DRIVEN VERTICAL TAKE-OFF TRANSPORT AIRPLANES. M.O. McKinney, R.E. Kuhn, and J.B. Hammack. (IAS 24th Annual Meeting, New York, Jan. 23--26, 1956, Preprint 597.) Aero. Eng. Rev., Apr., 1956, pp. 68-75. Summary of the Langley Aero. Lab. investigations covering stability and control, propellers, and aerodynamic characteristics of wing-propeller combinations. Results indicate that the principle of redirecting the slipstream as a function of flap-chord to propeller-diameter ratio may be applied to obtain slipstream angles of the order of 70°, with the diving moments and ground effects on these configurations controlled by lowering the thrust axis; and that high static thrust may be obtained by use of large diameter, considerable blade camber, and blade width.

WATER-BORNE AIRCRAFT

HYDRODYNAMIC IMPACT LOADS IN SMOOTH WATER FOR A PRISMATIC FLOAT HAVING AN ANGLE OF DEAD RISE OF 10°. P.M. Edge, Jr. US, NACA TN 3608, Jan., 1956. 20 pp. Experimental investigation in the Langley Impact Basin at impact fixed angles of trim of 3°, 12°, 20°, and 30° and at flight-path angles between 2° and 23°, with data used to evaluate theoretical and empirical means for the determination of the dead-rise function, aspect-ratio factor, and draft where chine-immersion effects occur. Analysis of test results indicates that the function of dead-rise angle in the determination of hydrodynamic loads is approximated by the expression $\frac{\pi}{2\beta} - 1$; that the experimental values of an aspect-ratio factor are in agreement with the Pabst-derived empirical expression; that, in the determination of draft where chine-immersion effects occur, the empirical value of $h(\beta) = 2.5\, f(\beta)$ is obtained as a function of dead-rise angle for water pileup at a 3° angle of trim; and that the experimental variations of load-factor, draft, and time coefficients, and velocity ratio are in agreement with the theoretical variation.

IMPACT MEASUREMENTS ON A LARGE MODEL OF A REPRESENTATIVE LANDPLANE FUSELAGE ON WATER. Appendix I - CALCULATION OF SPLASH-UP. J.E. Allen. Gt. Brit., MAEE Rep. F/Res/264, Oct., 1954. 73 pp. 17 refs. Experimental investigation of splash-up, impact pressures, and impact force occurring during controlled alightings on smooth water of a fuselage of elliptical cross-section in the Hull Launching Tank to determine an optimum fuselage-wing combination having good ditching characteristics, with pressure distributions for several landings over a range of initial altitudes and at flight path angles down to 1.5 degrees. Results indicate that the width of the actual wetted surface of the cylinder is $\sqrt{2}$ times the width that would be wetted for immersion to the same draft without splash-up; and that the current findings are not applicable generally to design cases for ditching until a rational theory of fuselage-shape impacts is conceived.

PRESSURE DISTRIBUTION ON A HYDROFOIL RUNNING NEAR THE WATER SURFACE. B.R. Parkin, Byrne Perry, and T. Yao-tsu Wu. CIT Hydrodynamics Lab. Rep. 47-2, Apr., 1955. 38 pp. 17 refs. Navy-sponsored investigation of the flow behavior about two geometrically similar Joukowski hydrofoils shallowly submerged to determine the effect of the free surface on the pressure distribution of the upper-side of the hydrofoil in a closed-circuit type water tunnel at sub-critical velocities using a Prandtl tube, standard pressure tape, and a Statham strain-gage transducer. Includes analyses of previously obtained data, derivation of the pressure coefficient in terms of Froude Number and the angle of attack, and a method to calculate lift and drag on a specific hydrofoil.

WIND TUNNEL TESTS ON SEAPLANE HULLS IN THE R.A.E. 5FT. DIAMETER OPEN JET TUNNEL AND THE N.P.L. COMPRESSED AIR TUNNEL. A.G. Smith. Gt. Brit., MAEE Rep. F/Res/266. Jan., 1955. 77 pp. Summary of the data of tests over a range of 2 to 60 x 10^6 Reynolds Numbers to determine the origin and order of the component drags of a hull and the difference from that of an equivalent body of revolution, to evaluate the scale effects and the possible effect of controlling the boundary layer transition, and the "Princess" flying boat step fairing design. Results indicate that the air drag need not exceed 1.05 to 1.10 times that of the corresponding body of revolution, and that the low hull drag is obtainable at all full scale Reynolds Numbers.

WIND TUNNELS AND RESEARCH FACILITIES

THE ELEVENTH BRITISH COMMONWEALTH AND EMPIRE LECTURE: THE GROWTH OF AERO-

NAUTICAL RESEARCH IN CANADA DURING THE POST-WAR DECADE. J.J. Green. J. RAeS, Dec., 1955, pp. 791--828. 79 refs. Includes a comprehensive review of the literature covering aerodynamic and hydrodynamic facilities for the study of gas dynamics, structures, flight turbulence, aerophysiology and aviation medicine, boundary-layer and shock-wave interaction, icing prevention and protection, fundamental combustion and heat transfer, automatic aircraft control, dynamic glider and parachute testing, aeroelasticity, engine thrust augmentation, missile aero-ballistics, free-flight techniques, and other problems of experimentation and development.

PAPERS PRESENTED AT THE JOINT SESSION OF THE FLIGHT TEST TECHNIQUES AND WIND TUNNEL AND MODEL TESTING PANELS, Ottawa, June, 1955. NATO AGARD Rep. AG18/P8, 1956. 134 pp. 27 refs. Contents: Modern Trends in Dynamic Stability Analysis and Experiment, H.G. Stever, J.T. Van Meter, E.E. Larrabee, Joseph Bicknell, and T.R. Parsons. An Investigation of Some Longitudinal Stability and Control Troubles at High Subsonic Speeds, E. Billion. Interpretation of Wind-Tunnel Data in Terms of Dynamic Behavior of Aircraft at High Angles of Attack, R.W. Stone, Jr. On-Line Automatic Data Reduction at the Arnold Engineering Development Center, D.F. Taylor. Comparison de Mesures en Vol et en Souffleries Portant sur les Caractéristiques d'un Avion dans le Subsonique Elevé, F. Vinsonneau. Some Comparisons between Wind Tunnel Model and Flight Test Results on Aircraft at High Angles of Attack, R.R. Duddy. Icing Experiments in Flight and Comparisons with Wind Tunnel Testing, D. Fraser.

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THE FLOW OVER A BODY IN A CHOKED WIND TUNNEL AND IN A SONIC FREE-JET. B.W. Marschner. J. Aero. Sci., Apr., 1956, pp. 368-376. Quantitative analysis at CIT of wall influences in the transonic region for application to closed throat wind-tunnel testing, with the computation of the pressure distribution over a double-wedge airfoil under free-flight conditions at M = 1 compared to the results from the wind-tunnel and sonic-free-jet measurements to indicate deviations and to establish criteria for tunnel corrections, as for the specific case of a wedge, having length of 13 per cent of the tunnel height and a thickness ratio 10 per cent in which the deviations of the pressure distribution barely exceed the usual experimental scatter.

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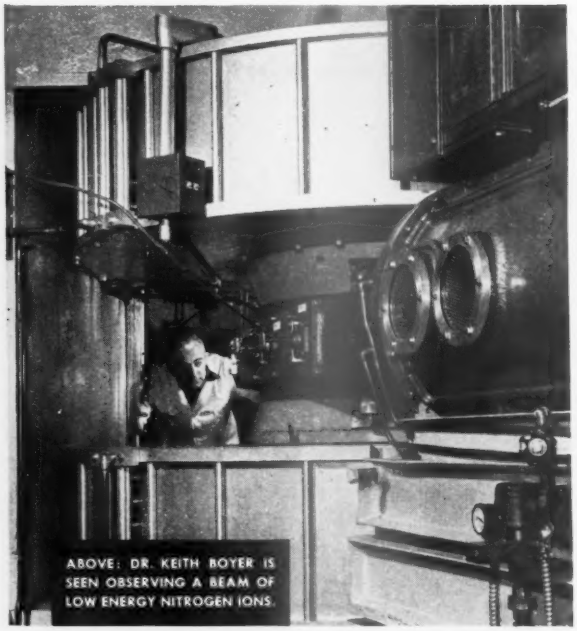

ABOVE: DR. KEITH BOYER IS SEEN OBSERVING A BEAM OF LOW ENERGY NITROGEN IONS.

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Thermal Stress

Influence of Aerodynamic Heating on the Effective Torsional Stiffness of Thin Wings. Appendix A. Appendix B—**Free-End Effect on Thermal Stress and Torsional Stiffness.** Bernard Budiansky and J. Mayers. *IAS 24th Annual Meeting, New York, Jan. 23–26, 1956, Preprint 579.* 27 pp. Members, $0.65; nonmembers, $1.00.

O Zagadnieniu Termosprężystym w Przypadku Ośrodków o Dowolnej Ortotropii Krzywoliniowej (On Thermoelastic Problems in the Case of a Body of an Arbitrary Type of Curvilinear Orthotropy). J. Nowiński, W. Olszak and W. Urbanowski. *Arch. Mech. Stosowanej* (Warsaw), Nov. 2, 1955, pp. 247–265. 13 refs. General theoretical development in terms of the classical equations of Duhamel and Neumann as applied to the cases of an unknown function which is the radial displacement of a thick-walled cylinder of infinite length with symmetrically circular temperature distribution, an analogous problem of a thin circular ring solved for the stress components, and a thick-wall sphere using a spherical type of elastic and thermal transversal orthotropy with the temperature assumed to be the function of the radius only in determining the state of stress.

Thermodynamics

Liquid-Vapor Phase Equilibrium in Solutions of Oxygen and Nitrogen at Pressures Below One Atmosphere. George T. Armstrong, Jack M. Goldstein, and D. Ellis Roberts. (*Res. Paper 2629.*) *U.S, NBS J. Res.*, Nov., 1955, pp. 265–277. 15 refs. USAF-sponsored investigation.

Heat Transfer

Elementi di Gasdinamica delle Miscele (Elements of Gasdynamics of Mixtures). II. Gianni Jarre. *L'Aerotecnica* (Rome), Aug., 1955, pp. 186–194. 10 refs. In Italian. Analysis of the phenomena of viscosity, conduction, and diffusion using thermodynamic methods for irreversible processes, with an evaluation of the hypotheses of these processes, particularly the Onsager theorem, as being basic to the kinetic theory of gases.

Experimental Investigation of Air-Flow Uniformity and Pressure Level on Wire Cloth for Transpiration-Cooling Applications. Patrick L. Donoughe and Roy A. McKinnon. (*U.S., NACA RM E52E16*, 1952). *U.S., NACA TN 3652*, Jan., 1956. 28 pp.

The Thermal Conductivity of Liquid and Gaseous Oxygen. H. Ziebland and J. T. A. Burton. *Brit. J. Appl. Phys.*, Dec., 1955, pp. 416–420. 13 refs.

Vertical Take-Off Aircraft

Technical Aspects of Steep-Gradient Aircraft. Maurice A. Garbell. *Interavia*, Jan., 1956, pp. 27–34. Analysis of design problems, trends, and potentialities, including a tabular breakdown of the main categories of powered aircraft in major flight phases.

Water-Borne Aircraft

Hydrodynamic Impact Loads in Smooth Water for a Prismatic Float Having an Angle of Dead Rise of 10°. Philip M. Edge, Jr. *U.S., NACA TN 3608*, Jan., 1956. 20 pp.

Hydro-Ski Development at Saunders-Roe. II. P. G. Fielding. *Saro Prog.*, Winter, 1955, pp. 10–14. Review of hydrodynamic engineering and problems, with results of design tests on models.

Return of the Seaplane. Joseph Goodyear. *Ordnance*, Jan.-Feb., 1956, pp. 593–597. Developmental survey of design trends and potentialities.

Wind Tunnels & Research Facilities

The Eleventh British Commonwealth and Empire Lecture: The Growth of Aeronautical Research in Canada During the Post-War Decade. J. J. Green. *J. RAeS*, Dec., 1955, pp. 791–828. 79 refs. Includes a comprehensive review of the literature.

Note on the Accuracy of Supersonic Tunnels. R. E. Meyer. *J. RAeS*, Dec., 1955, p. 847. Method to obtain criteria for measurements of aerodynamic forces in terms of interference corrections for the production of sufficiently accurate nozzles as applied to the case of drag of an airfoil in two-dimensional supersonic flow calculated by a pressure traverse downstream.

Problems Associated with the Design and Construction of Wind Tunnels. E. F. Burford. *Brit. Welding J.*, Dec., 1955, pp. 541–549. Includes analyses of such factors as high operating temperatures, vibration, drumming, and noise.

Instrumentation of GALCIT Hypersonic Wind Tunnels. Paul E. Baloga and Henry T. Nagamatsu. *GALCIT Memo 29*, July 31, 1955. 28 pp.

(*Continued on page 197*)

Aeronautical Reviews — BOOKS

ACOUSTICS

Acoustic Principles, Practical Application. D. J. W. Cullum. London, E. & F. N. Spon, Ltd., 1955. 200 pp., diagrs., tables. $2.00.

A reprint of the 1949 edition. Its purpose is to provide in concise form information dealing with architectural acoustics and soundproofing in buildings.

AIRPORTS

Minutes of the Eighth Annual Airport Development and Operation Conference, Syracuse, N.Y., September 27, 1955. Albany, New York State Department of Commerce, 1956. 95 pp.

Contents: Developing a Strong Airport Community Relations Program, C. E. Rosendahl. Small Aircraft—Can They Pay Their Way, John M. Harris. Aviation's Role in the New York State Economy, Edward T. Dickinson. Problems of Air Traffic Control, Panel Discussion. Airport Fire and Crash Protection, Panel Discussion. Canada's Elementary Flying Training Program, G. C. McDonald.

COMPUTERS

A Survey of Automatic Digital Computers. N. M. Blachman, J. B. Kruskal, Jr., J. J. Wolf, and D. L. Hogan. (U.S., Office of Naval Research.) Office of Technical Services, 1955. 109 pp., tables. $2.00.

This survey presents data on nearly 100 automatic digital computers intended for more or less general-purpose computation. For the most part, this information was obtained by means of questionnaires during the month of February, 1953. For each computer, pertinent data are given in standard tabular form under such headings as: Built by; Installations; Programming Service; Computing Time; Floor Area; Cooling; Best Suited for; Power Consumption; Word Length; Operations (Performed); Computing Element; Components, etc. Explanation of necessary terms is given in the introduction, and three indexes give a list of computers by name, a list of the builders, and the geographical location of both the builders and the computers.

DIRECTORIES

The Aviation Industry—A Report on Plants and Facilities. Edited by Hugh C. Judge. New York, AERONAUTICAL ENGINEERING REVIEW, 1956. 32 pp.

This directory lists the plants and facilities of organizations in the United States known to be engaged in original work in research, design, and final assembly phases of aircraft, missile, and power-plant development. A special listing of wind-tunnel installations is included, giving the location of each facility, type of tunnel, size of test section, and flow velocity.

Contents: (1) The Aviation Market. (2) Regional Breakdown of Aircraft Plants & Facilities. (3) Manufacturing Plants: Military & Large Transport Aircraft; Light Aircraft; Helicopters, Convertiplanes, & VTO; Guided Missile, Rocket, & Pilotless Aircraft; Aircraft Engines. (4) Government Research and Test Facilities. (5) U.S. Wind Tunnel Facilities. (6) Wind Tunnel Installations: Government; University; Privately Owned.

ELECTRONICS

Advances in Electronics and Electron Physics, Vol. 7. L. Marton, Editor. New York, Academic Press, Inc., 1955. 527 pp., illus., diagrs., tables. $11.50.

Originally titled "Advances in Electronics," the series' permanent title is now "Advances in Electronics and Electron Physics." This volume combines physical and engineering electronics with electron physics. The emphasis is on related solid-state phenomena.

Contents: The Physics of Semiconductor Materials, Elias Burnstein and Paul H. Egli. Theory of the Electrical Properties of Germanium and Silicon, Harvey Brooks. Characteristic Energy Losses of Electrons in Solids, L. Marton, Lewis B. Leder, and H. Mendlowitz. Sputtering by Ion Bombardment, Gottfried K. Wehner. Observational Radio Astronomy, J. P. Wild. Analog Computers, A. W. Vance, E. C. Hutter, J. Lehmann, and M. L. Wadlin. Electrical Discharge in Gases and Modern Electronics, L. Goldstein.

Proceedings of the RETMA Symposium on Automation. University of Pennsylvania, September 26, 27, 1955. Sponsored by the Engineering Department of the Radio-Electronics-Television Manufacturers Association. New York, Engineering Publishers, 1956. 114 pp., illus., diagrs. $5.00.

Contents: A System for Automatic Production of Electronic Assemblies, Cledo Brunetti and George Kwasniewski. Design and Manufacture of Automation Components, Louis Kahn. Obtaining Reliability and Versatility in High Production Mechanized Assembly Equipment, Joseph Harrington, Jr. Sylvania Automatic Assembly Equipment and its Application to a 5-Tube AC/DC Radio Chassis, Carl F. Carlzen. Milestone of Automation, D. A. Griffin. Factory Automation by Digital Control, J. A. Potter. An Automated Ticket Reservation System, Craig Andrews. Automatic Warehousing, Gifford Kittredge. Automation of Non-Circular Gear Cutting by UNIVAC-120, A. H. Stillman and F. W. Cunningham. The Future of Automation—Panel Discussion. "Minn-A-Matic," a Machine for Short Run Production, D. F. Pennie. A Functional Approach to Automatic Systems and Standardization, F. C. Collins and K. Hesdoeffer. The Production of Electronic Circuits by Mechanized Wiring, S. J. Begun and Felix Rosenthal. Automation and Subminiature System, R. J. Roman. Redesign for Automatic Production of Electronic Equipment, M. R. Johnson. Signal Corps Component Program for Automation, S. F. Danko and R. A. Gerholdt. Automation from the Component Manufacturers' Viewpoint, J. D. Heibel and James H. Foster. Philosophy of Component Design and Packaging for Mechanized Assembly of Printed Wiring Boards, R. B. Lynn.

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EQUIPMENT, HYDRAULIC & PNEUMATIC

Hydraulic and Pneumatic Operation of Machines. H. C. Town. New York, Philosophical Library, 1956. 191 pp., illus., diagrs., tables. $7.50.

H. C. Town is the Head of the Engineering Department of Keighley Technical College and has prepared his book for the student, as well as for the engineer and designer in all branches of general and production engineering. The more recent developments in fluid power transmission are concerned with pressure applied to the operation of industrial machinery, and it is for this growing aspect of hydraulics that the author intends to provide practical information. Additionally, the material deals with the use of pneumatic power which may be correlated with, or have similar applications to, that of hydraulic transmission.

Part I of the book describes the advantages and limitations of oil for power transmission and shows the main types of pumps used. A chapter is devoted to the important and little-known advantages of the hydraulic rotary drive. Modern accumulator systems are described, then hydrokinetic transmission. This chapter includes diagrams of fluid coupling and torque-converters with descriptions of their applications to modern automatic gear-changing devices.

Part II, dealing with pneumatic developments, includes chapters on air compressors and structural details, the operation and maintenance of pneumatic tools, and the design of pneumatic circuits. The subject of air-operated jigs and fixtures is discussed, followed by industrial applications of air control of brakes, clutches, conveyors, and aircraft components. The book concludes with examples of hydropneumatic devices dealing with oil control of air pressure, and describes circuit control design, tracer-controlled copying devices, and aircraft components.

FLUID DYNAMICS

Fluid Dynamics of Jets. Shih-I Pai. New York, D. Van Nostrand Company, 1954. 227 pp., illus., diagrs. $5.00.

Shih-I Pai, Associate Professor at the Institute for Fluid Dynamics and Applied Mathematics, University of Maryland, presents the experimental and theoretical facts about the steady flow of a jet of gas issuing from a nozzle into the surrounding stream at rest or in uniform motion. The book is intended not only as an introduction to this problem for advanced students in aerodynamics but also as a reference for research workers in this field. There is a wide range of practical applications in problems of propulsion, external flow and testing of live rockets and jets,

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jet pump design, flow mixing processes, heat transfer, hydraulics, and air pollution. The theoretical methods discussed are also applicable to the study of the problems of wakes and cavitation. Bibliography is cited at the end of each chapter. There is a detailed breakdown of material discussed under the following chapter headings: (1) Flow of a Jet of Inviscid and Incompressible Fluid. (2) Subsonic Flow of a Jet of Inviscid Fluid. (3) Supersonic Flow of a Jet of Inviscid Fluid. (4) Laminar Flow of a Jet of Viscous Fluid. (5) Turbulent Flow of a Jet of Incompressible Fluid. (6) Turbulent Flow of a Jet of Compressible Fluid. (7) Jet Mixing of Gases of Different Kinds. (8) The Stability of a Jet of Incompressible Fluid. (9) Stability of a Jet of Compressible Fluid. Appendix.

MANPOWER

Papers of the Fourth Conference on Scientific Manpower; 121st Meeting of the American Association for the Advancement of Science, Berkeley, Calif., December, 1954. Washington, D.C., National Science Foundation, 1955. 47 pp., diagrs., tables.

Contents: Implications for Natural Science, L. A. Durbridge; Comments, Marsh W. White. Implications for Social Science, Conrad Taeuber; Comments, Donald W. Taylor. Implications for Science Teaching, Ralph W. Tyler; Comments, John R. Mayor. Estimated Volume of Research and Development Expenditures by Federal Government in 1955, Raymond H. Ewell. Estimated Volume of Research and Development Expenditures by Industry in 1955, A. L. Lyman; Comments, J. E. Hobson. Selective Service and Military Reserve Developments, Carl Hinshaw.

MATERIALS

Plastic Progress, 1955; Papers and Discussions at the British Plastics Convention, 1955. Edited by Phillip Morgan. London, Iliffe & Sons; New York, Philosophical Library, 1956. 432 pp., illus., diagrs., tables. $17.50.

Contents: The Synthesis of New Types of Addition Polymers, H. W. Melville. Discussion on "Polymer Structure and Properties." Recent Advances in the Radiation Treatment of Polymers, A. Charlesby. The Molecular Weight of Polythene—Its Measurement and Significance, S. W. Hawkins. Discussion on "Polymer Structure and Properties." The Chemistry of Modern Blowing Agents, R. A. Reed. The Technology and Uses of Polyurethane Foams, L. N. Phillips. Discussion on "Expanded Plastics." Dispersion of Polytetrafluoroethylene, H. M. Whitcut. New Nylon Polymers and Compositions, R. H. Birtles. Discussion on "Thermoplastics." Fundamental Problems of Single-Screw Thermoplastic Extruders, E. Gaspar. Discussion on "Extrusion." Work Study and the Plastics Industry, J. Grange Moore. Productivity and Methods in Moulding, A. L. Sparshott. Discussion on "Work Study and Productivity." The Effect of Injection Moulding Variables on the Quality of Mouldings, K. C. Bryant and G. Hulse. Discussion on "Injection Moulding." Recent Advances in Injection Moulding Techniques and in the Evaluation of Moulding Materials, G. Campbell and L. L. Griffith. Runners, Gates, and Vents for Thermoplastic Moulds, A. G. Elwell. Discussion on "Injection Moulding." Patents and the Plastic Industry, a Chartered Patent Agent. Discussion on Patents. Development in the Use of Plastics in the Foundry, P. G. Pentz. Discussion on "Foundry Resins." Consistency in Glass Fibre Reinforced Moulding, J. Rees. Glass Reinforced Plastics in Automobile Construction, H. Silman. Discussion on "Glass Reinforced Plastics." Chemical Engineering Possibilities in Glass Reinforced Plastics with Special Reference to Polyester Resins, J. R. Stevenson and V. Evans. The Testing and Development of High Quality Glass Fibre/Polyester Laminates, P. H. H. Bishop and E. Haythornthwaite. Epoxide Resin/Glass Laminates, W. J. Marmion. Discussion on "Glass Reinforced Plastics." Subject Index.

MATHEMATICS

Numerical Analysis, With Emphasis on the Application of Numerical Techniques to Problems of Infinitesimal Calculus in Single Variable. Zdeněk Kopal. New York, John Wiley & Sons, 1955. 556 pp., tables. $12.

This is an introduction to the numerical analysis of the functions of a single real variable based on courses given by the writer to students of science and engineering at Massachusetts Institute of Technology between 1947 and 1951. The author is now Professor of Astronomy at the University of Manchester. In a systematic manner he develops the analytical basis of such numerical processes as are necessary for an algebraization and numerical solution of a wide range of problems of the infinitesimal calculus which are encountered daily in physics or engineering but which are not amenable to solution by formal mathematical methods. His aim has been to provide an advanced undergraduate textbook, as well as a research handbook for certain branches of numerical analysis. There are frequent numerical examples to illustrate many of the points.

METALS & ALLOYS

Steels for the User. R. T. Rolfe. 3rd Ed., Revised and Enlarged. New York, Philosophical Library, 1956. 399 pp., illus., diagrs., tables. $10.

The lapse of 13 years since the publication of the second edition has necessitated a considerable amount of revision. The text has been increased 15 per cent and the illustrative matter 17 per cent. The book deals substantially with carbon steels; alloy steels are discussed only for the duties for which carbon steels are unsuitable, as with nitriding steels and those for high-temperature services.

Titanium. A. D. McQuillan and M. K. McQuillan. New York, Academic Press; London, Butterworths Scientific Publications, 1956. 466 pp., illus., diagrs., tables. $10.

This is the fourth in the series, "Metallurgy of the Rarer Metals," under the editorship of H. M. Finniston, Head of the Metallurgy Division, Atomic Energy Research Establishment, Harwell, Berkshire. The authors present a full account of the basic properties of titanium metal and its alloys rather than the details of its industrial technology. Nevertheless, since titanium technology is unusually dependent on the fundamental nature of the metal, the principles involved in all aspects of the production and processing of titanium on an industrial scale have been discussed. Each chapter has been written bearing in mind the needs of those readers most likely to be interested in the particular aspect of the subject concerned. A unique and helpful feature of the book is the detailed subdivision under each chapter head which transforms the Table of Contents into a valuable adjunct to the Subject Index.

Contents: (1) History and Occurrence of Titanium. (2) Recovery of Titanium Metal from its Ores. (3) Purification of Titanium. (4) Melting and Casting of Titanium and its Alloys. (5) Fabrication and Joining of Titanium. (6) Physical Properties of Titanium. (7) Constitution of Titanium Alloys. (8) Deformation Mechanisms and Textures. (9) Transformations in Titanium and Titanium Alloys. (10) Mechanical Properties of Titanium. (11) Heat-treatment and Mechanical Properties of Titanium-rich Alloys. (12) Reaction of Titanium with Gases. (13) Corrosion of Titanium. (14) Metallographic Techniques for Titanium and its Alloys.

METEOROLOGY

Rain-Making, Its Present Position and Future Possibilities. A. K. Roy. New Delhi, Council of Scientific & Industrial Research, 1955. 31 pp., illus., diagrs. 60 refs.

NAVIGATION

2nd Technical Symposium on TACAN, Nov. 3–4, 1955, Washington, D.C. U.S. Air Navigation Development Board. Washington, D.C., 1956. 1 vol., illus., diagrs., tables.

Contents: Introduction to the General System Session, John L. Loeb. The TACAN System, Sven H. Dodington. Propagation Aspects of TACAN System Coverage, Martin D. Decker. TACAN System Evaluation, J. S. Prichard. Evaluation of the TACAN System, Technical Development Report No. 261, R. C. Borden, T. W. Wonnel, R. B. Flint, S. L. Kades, and J. R. Hoffman. Azimuth Errors of the TACAN System, DeWitt T. Latimer, Jr. TACAN System Evaluation, J. R. Knight. The AN/URN-3, T. M. Douglas. The AN/URN-3 Antenna, Anthony M. Casabona. The AN/URN-3 Antenna (Field Experience), Robert A. Olson. Description of MX-1627/URN-3, Monitor Equipment for AN/URN-3, E. Bradburd. Test Equipment for the AN/URN-3, D. Laurence Jaffe. The AN/ARN-21, Archie F. Boscia. ARN-21 Instrumentation in Use with TACAN, Milton Brown. TACAN Test Equipment, Lloyd C. Downes. Problems Encountered During the Installation of AN/ARN-21 Equipment "TACAN" in Military Aircraft, Robert J. Klessig. Report on the AN/ARN-21 (XN-10) Program, John C. McElroy. AN/URN-3 New Antenna Development, R. M. Sprague. Low Power TACAN, William J. Ward. Common System Application, DeLoss K. Martin.

POWER PLANTS

Aircraft Gas Turbines. C. W. Smith. New York, John Wiley & Sons, 1956. 448 pp., diagrs. $8.75.

The material contained in this book is essentially that covered by the author in his courses at the Daniel Guggenheim School of Aeronautics, New York University, where he has been Adjunct Professor of Aeronautical Engineering since 1946. Similar courses during the same period have been given to engineers of the Aircraft Gas Turbine Division, General Electric Company. For security reasons, and since details vary widely and change rapidly, the material presented is limited to fundamentals. Included are sufficient thermodynamic and aerodynamic theory for a full understanding of the subject. This is the first book to adopt throughout the practice of expressing the equations in terms of the isentropic factor x. This method results in considerable simplification of equations and greater ease of calculation (tables of x are provided in the text). Although nearly all equations are presented in a physical form so that they are independent of units and of maximum generality, "working" equations are also given where needed.

Contents: (1) Introduction. (2) Elementary Principles of Aircraft Propulsion. (3) The Brayton Cycle. (4) Cycles Derived from the Basic Brayton Cycle. (5) Other Gas Turbine Cycles. (6) Elementary Gas Dynamics. (7) Theory of Flow in Ducts, Nozzles and Diffusers. (8) Intake and Exhaust Systems of Aircraft Gas Turbine Power Plants. (9) Transfer of Energy Between a Fluid and a Rotor. (10) Centrifugal Compressors. (11) Axial-Flow Compressors. (12) Turbine and Exhaust System. (13) Combustion Chamber. (14) Elements of Dynamic Similarity. (15) Working Criteria. (16) Control and Accessories. (17) Stresses and Materials. (18) General Performance and Installation. Appendix. Bibliography.

Solid Propellant Rockets. Alfred J. Zaehringer. Wyandotte, Mich., American Rocket Co., 1955. 162 pp., illus., diagrs., tables. $4.00.

Written for the engineer or scientist, this book is a general introduction to the field of solid propellant rockets. Some sections, such as that on testing, are also applicable to liquid propellant rockets and should prove useful to those involved in that particular field. Mr. Zaehringer, President of the American Rocket Co., is aware of the limitations of a general treatment and has begun work on two companion volumes to implement and supplement the present edition, particularly in the field of propellants and combustion. Bibliographies and a list of references, a table of symbols, a glossary, and author and subject indexes are provided.

Contents: (1) Introduction and History. (2) Interior Ballistics. (3) Processing. (4) Exterior Ballistics. (5) Static Testing. (6) Dynamic Testing. (7) Applications.

RESEARCH

Proceedings of the Ninth Annual Conference on the Administration of Research, September 7–9, 1955, Northwestern University Technological Institute, Evanston, Ill. New York, New York University Press, 1956. 107 pp. $4.00.

Contents: Research Relationships Today and Yesterday: Research Relationships Between Government and the University, Ralph A. Morgen. Research Relationships Between Government and Industry. Daniel P. Barnard.

Current Views on Research Relationships: Summary of Statistical Data on Government-Sponsored Research, Raymond H. Ewell. University Executives' Viewpoints on Government Research Relationships, J. W. Buchta. Industry Executives' Viewpoints on Government Research Relationships, Allen Abrams.

Industry and University as Sources of Research for Government: Industry and University as Sources of Research Operations for the Armed Services, D. L. Putt. Industry, Universities, and National Laboratories as Sources of Research Operations for the Atomic Energy Commission, Thomas H. Johnson.

Improving Research Relationships: How Can Methods of Obtaining and Awarding Contracts be Improved, Morris T. Carpenter. How Can the Working Relations Between Contractors and Government Administrators be Improved, John H. Richardson. Closing Remarks, R. W. Cairns.

Summaries of Group Discussions: Negotiating and Procuring the Contract, William Davis. Effective Relations in Government-Sponsored Research, Thomas Killian. Utilizing Research Results, Charles Kimball. Communications in Research, Oscar Maier.

The Future of Research: For Industry, E. D. Reeves. For Universities, Clifford C. Furnas. For Government, H. Guyford Stever.

ROTATING WING AIRCRAFT

Helicopter Navigation Requirements. F. Dorn Barclay and Gordon S. Wiley. Menlo Park, Calif., Stanford Research Institute, 1955. 97 pp., diagrs., tables.

This report, prepared for Bendix Aviation Corporation, presents the probable requirements for aids to helicopter navigation in the period 1958–1965. Factors of time and economics as they are affected by operations over various suggested helicopter routes are analyzed. This analysis indicates the relative merit of helicopter operations along established airways versus direct city to city operations. The results indicate a requirement for an area-coverage system of navigation aids. A typical military mission is investigated. Within the limits of the postulated mission parameters, a method of operation is suggested, and navigation accuracy requirements are determined. The report also presents a brief investigation of the relationship between operating frequency and complexity for a radio aid and a discussion of the influence of rotor blade modulation on the design of a radio aid. Market factors pertaining to helicopter navigation aids are given as a guide to future sales planning.

SPACE TRAVEL

200 Miles Up; The Conquest of the Upper Air. J. Gordon Vaeth. 2nd Ed. New York, The Ronald Press Co., 1951. 261 pp., illus., diagrs. $5.00.

The White House announcement on July 29, 1955, that the United States will launch minimum earth-circling satellites during the International Geophysical Year has re-emphasized the importance of high-altitude exploration. This second edition of Mr. Vaeth's book gives an account of the whole American program of upper air research and relates this program to its latest

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development, the artificial satellite. The major portion of this book is devoted to a description of the atmospheric ocean and the vehicles, equipment, and techniques employed to sound it. Specific chapters deal with the V-2, Aerobee, and Viking firings at the White Sands Proving Ground and on shipboard, as well as the probing of the sky by use of Skyhook balloons. The performance of these vehicles and the scientific findings made possible through their complex instrumentation are evaluated. Looking toward the future, the author attempts to predict the shape of high-altitude things to come and, in a chapter on "The Minimum Satellite," describes the principles inherent in this unique type of research vehicle. In the closing chapter, "Beyond the Earth," the author, in order to stress that the upper atmosphere and minimum satellite programs of today will become the space research programs of tomorrow, gives his own portrayal of the future evolution of flight beyond this planet.

STRUCTURES

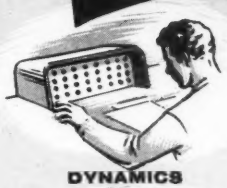
Proceedings of the Society for Experimental Stress Analysis, Vol. 13, No. 1. Edited by C. V. Mahlmann and W. M. Murray. Cambridge, Mass., The Society, 1955. 213 pp., illus., diagrs., tables. $6.00.

Contents: Electrical Analog Solution of Certain Non-Linear Problems in Vibration and Elastic Stability, F. R. Berry, Jr. Influence of Fluid Pressure on SR-4 Strain Gages, H. Majors, Jr. Conventional Wire Strain Gage Used as a Principal Stress Gage, H. R. Lissner and C. C. Perry; Discussion, P. D. Flynn. Further Studies on Properties and Stresscoat, A. J. Durelli, R. H. Jacobson, and S. Okubo. Discussion of Papers Entitled: "Study of Some Properties of Stresscoat" (Vol. 12 No. 2) and "Further Studies of Properties of Stresscoat," F. B. Stern, Jr. Letter to the Editor: Advances in the Art of Stresscoat Analysis, E. C. Clark. Deviations from Straightness of Carefully Machined and Centered Columns, B. Erickson, S. V. Nardo, and N. J. Hoff. Basis for the Design of a Three-Dimensional Ballistocardiograph, D. M. Cunningham and G. W. Brown. An Investigation of the Dynamic Properties of Plastic and Rubber-Like Materials, E. Volterra, R. A. Eubanks, and D. Muster. Fillets Without Stress Concentration, R. Lansard. Structural Design Problems in Gas Turbine Engines, P. N. Bright. A Miniature Oscilloscope and Vibration Pickup for Nodal Pattern Tracing, S. N. Shafer and R. Plunkett. Pressure Tank and Instrumentation Facilities for Studying the Strength of Vessels Subjected to External Hydrostatic Loading, E. E. Johnson. Barium Titanate Strain Gages, J. W. Mark and W. Goldsmith. The Use of Foil Gages to Measure Large Strains Under High Fluid Pressure, M. C. Steele and L. C. Eichberger. Strain Gage Applicator, S. W. Leszynski. Prediction of Brittle Coating Strain Sensitivity Based on a Statistical Regression Analysis, J. W. Dally and A. J. Durelli. The NACA Combined Load Testing Machine, R. W. Peters. A Response Spectrum Analyser for Transient Loading Studies, T. K. Caughey and D. E. Hudson. Stress Gradients in Grooved Bars and Shafts, M. M. Leven.

WATER-BORNE AIRCRAFT

The Next 20 Years: 1955–1975. Hoboken N.J. Experimental Towing Tank, Stevens Institute of Technology, 1955. 46 pp., illus., diagrs.

Contents: On Twentieth Anniversaries; A Clinical Study, K. S. M. Davidson. Influence of Sea Conditions on the Speed of Ships, Edward V. Lewis. Fractional Replication, a New Tool. Future Submerged Hydrodynamic Research, Bruen H. Peters. An Experimental Towing Tank for Small Models, Kenneth S. M. Davidson. The Future of Computers, S. M. Shackell. Capsule History of Experimental Towing Tank. Future Aspects of Motor Vehicles. Future Trends of Water-Based Aircraft. Dan Savitski.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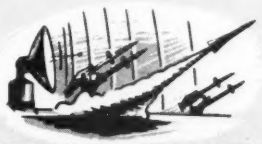
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INDEX TO ADVERTISERS seeking Engineering Personnel

COMPANY and LOCATION	PAGE
Arma Division, Garden City, N.Y.	196
Avco Defense & Industrial Products, Stratford, Conn.	131
Bell Aircraft Corp., Buffalo, N.Y.	137
Boeing Airplane Co., Seattle, Wash.	157
Combustion Engineering, Inc., New York, N.Y.	192
Convair Division	
Pomona, Calif.	193
San Diego, Calif.	125
Cornell Aeronautical Laboratory, Buffalo, N.Y.	194
Curtiss-Wright Corp., Wood-Ridge, N.J.	159
De Laval Steam Turbine Co., Trenton, N. J.	161
Douglas Aircraft Co., Inc., Santa Monica, Calif.	121
Experiment Inc., Richmond, Va.	161
Fairchild Aircraft Division, Hagerstown, Md.	132
International Business Machines Corp., Endicott, N.Y.	190
Johns Hopkins University, Applied Physics Laboratory, Silver Spring, Md.	194
Kearfott Co., Inc., Clifton, N.J.	161
Lockheed Aircraft Corp., Atlanta, Ga.	129
California Division, Burbank, Calif.	145
Missile Systems Division, Van Nuys, Calif.	19
Los Alamos Scientific Laboratory, Los Alamos, N.M.	186
Marquardt Aircraft Co., Van Nuys, Calif.	159
The Glenn L. Martin Co., Denver, Colo.	168
North American Aviation, Inc.	
Columbus, Ohio	165
Downey, Calif.	143
Los Angeles, Calif.	154
Olin Mathieson Chemical Corp., N.Y.C.	159
Reaction Motors, Inc., Denville, N.J.	159
Trans World Airlines, Kansas City, Mo.	194
University of Minnesota, Rosemount, Minn.	192

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(*Continued from page 188*)

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Temperature Control of Blow-Down, Supersonic Tunnels. T. A. Thomson. *J. RAeS*, Jan., 1956, pp. 67–70. Review of experimental and operational data covering factors of pressure compensation, heat addition, and temperature restoration from stored heat.

A Method of Boundary Layer Flow Visualisation for Use in Flight. P. B. Atkins and R. S. Trayford. *Australia, ARL FN 22*, July, 1955. 15 pp. Adaptation of the china clay technique.

A Schlieren System for Perforated Wall Type Transonic Wind Tunnels. Appendix—**Factors Affecting the Sensitivity of the Multiple-Source Schlieren.** Eugene Behun. *USAF WADC TR 54-511*, Dec., 1954. 38 pp.

A Wide Range Schlieren System. H. Jeffree. *J. Sci. Instr.*, Jan., 1956, pp. 29, 30. Development of methods to obtain high sensitivity and fine detail simultaneously required for wind-tunnel flow-visualization problems.

Methods of Determination and of Fixing Boundary Layer Transition on Wind Tunnel Models at Supersonic Speeds. K. G. Winter, J. B. Scott-Wilson, and F. V. Davies. *Gt. Brit., ARC CP 212* (Sept., 1954), 1955. 27 pp. 21 refs. BIS, New York. $0.75.

Model Testing Technique Employed in the R.A.E. Seaplane Tank. Appendix I—**Longitudinal Instability Characteristics.** Appendix II—**Spray and Wake Formation.** T. B. Owen, A. G. Kurn, and A. G. Smith. *Gt. Brit., ARC R&M 2976* (Sept., 1953), 1955. 59 pp. 23 refs. BIS, New York. $3.75.

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Index to

A

AC Spark Plug Division, General Motors Corporation 107
Aeronautical Engineering Catalog 153, 167
Aeronautical Engineering Review 192
AiResearch Manufacturing Divisions, The Garrett Corporation 15
Allison Division, General Motors Corporation 89
American Machine & Foundry Company 16
★American Phenolic Corporation 146
★American Steel & Wire Division, United States Steel Corporation 30
Arma Division, American Bosch Arma Corporation ..... Inside Front Cover, 196
★Avco Defense and Industrial Products
Crosley Division 99
Advanced Development Division 131

B

Bell Aircraft Corporation 136, 137, 138
Boeing Airplane Company 157

C

★Cannon Electric Company 124
Century Electronics & Instruments, Inc. 163
★Chain Belt Company, Shafer Bearing Division 113
Chance Vought Aircraft, Inc. 26
Combustion Engineering, Inc. 192
CONVAIR, A Division of General Dynamics Corporation 125, 193
Cornell Aeronautical Laboratory, Inc. 194
Curtiss-Wright Corporation 159

D

De Laval Steam Turbine Company 161
★Douglas Aircraft Company, Inc. 22, 121

E

Eagle Pencil Company 18
Eckel Corporation, The 151
★Electrical Engineering & Manufacturing Corporation 29
Ex-Cell-O Corporation 91
Experiment Incorporated 161

F

Fairchild Engine and Airplane Corporation
Fairchild Aircraft Division 32, 132
★Stratos Division ..... Back Cover
Fenwal Inc., Aviation Products Division 31
★Flexonics Corporation, Aircraft Division 108
Foote Bros. Gear and Machine Corp. 123
Fluid Regulators Corporation 109
Carl L. Frederick & Associates 153

G

Garrett Corporation, The, AiResearch Manufacturing Divisions 15
General Dynamics Corporation, CONVAIR Division 125, 193
General Electric Company 25
General Motors Corporation
AC Spark Plug Division 107
Allison Division 89
Harrison Radiator Division 149
General Precision Equipment Corporation 4, 5
General Radio Company 20
★G. M. Giannini & Company, Inc. 21
B. F. Goodrich Company, The 8, 9

H

Hall-Scott Motors Company, Electronics Division ..... Inside Back Cover
Harrison Radiator Division, General Motors Corporation 149
Hoover Electric Company 7
★Huck Manufacturing Company 115
Hydro-Aire, Inc. 114

I

International Business Machines Corporation 190
International Nickel Company, Inc., The 27

J

Johns Hopkins University, The 194
★Johns-Manville 10

K

★Kawneer Company, Aircraft Products Division 23
★Kearfott Company, Inc. 102, 161
Kollsman Instrument Corporation 111

L

Lamb Electric Company, The 96
★Lear, Inc. 134, 135
Lockheed Aircraft Corporation 92, 93, 129